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Vol. 183 FEBRUARY, 1917 No. 2

THE DEVELOPMENT OF THE CERAMIC INDUSTRIES IN THE UNITED STATES.*

BY

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THE most ancient of the industries, that dealing with the molding and firing of clay forms, one of the last strongholds of pure empiricism, is giving way under the pressure of scientific advance and is undergoing decided changes at the present time. The first impetus towards the employment of scientific methods in the solution of ceramic problems was due principally to the work of Hermann August Seger in the late eighties, and his writings have proved the basis on which later developments have been built up. Of late the influence of physical chemistry in its several branches has made itself felt.

Clays are mixtures of usually finely-divided hydrous aluminum silicates with coarser granular matter, such as quartz, feldspar, mica, etc. There are represented all grades of subdivision, from the coarsest to the finest. The property of plasticity, the ability of the substance to be molded when admixed with water

* Presented at the meeting of the Section of Physics and Chemistry, held Thursday, November 2, 1916.

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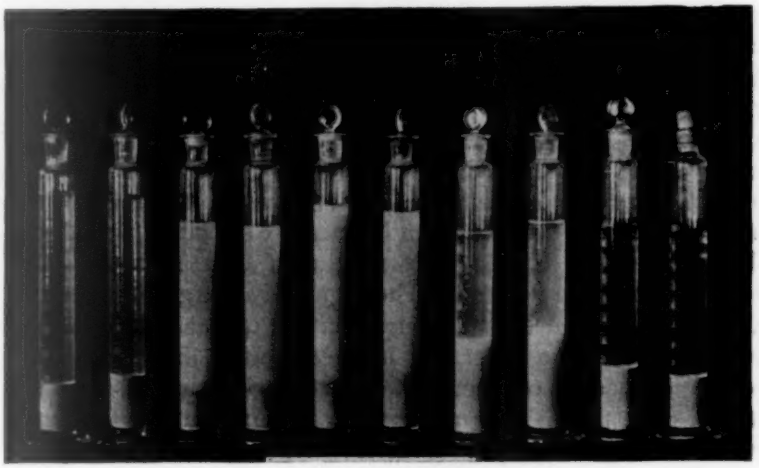
and to retain the shape imparted to it, is to be attributed to the dispersed state of the aluminum silicates known under the general term of clay substance. Indeed, a portion of the mass making up clays may be considered to possess the properties of a suspensoid colloidal system. Organic coloids and electrolytes influence the latter to a very considerable extent. The aluminum silicates, by virtue of their very complex constitution, their content of OH groups, and their slight solubility in water, are inclined to be more stable in the amorphous than in the crystalline state.

The effect of electrolytes upon clays suspended in water, as well as in the plastic state, is of a far-reaching character. Thus, alkalies, such as sodium hydroxide and sodium carbonate, tend to increase the degree of dispersion of the clay particles and to reduce the viscosity of the suspension in a decided manner. This may be readily illustrated by adding a small amount of caustic soda to a clay suspension, when it will be found that a portion of the clay will become so fine that it will pass through filter paper, a condition which did not exist before. Again, by determining the viscosity of the clay suspension by means of a simple form of flow viscosimeter, it will be found that the fluidity of the system is greatly increased by the alkali addition, frequently as much as 100 per cent., and more. The effects thus noted are evidently due to the action of the negatively charged OH ions. These repel the similarly charged clay particles electrostatically and thus they increase the state of dispersion of the system, breaking up the larger aggregates into smaller particles. The water hence penetrates more deeply into the clay structure and causes the clay to "liquefy." A clay suspension in this condition will hold up the fine particles of clay substance while the granular material, due to the decreased viscosity of the system, will settle out promptly. The maximum effect of this action, known as deflocculation, is brought about by a definite concentration of OH ions, and if this is exceeded the reverse effect will be produced, shown by increased viscosity and "stiffening." This stage may again be followed by a second drop in viscosity by adding additional amounts of alkali or by allowing the suspension to stand. In the latter case the effect is due either to adsorption of the salts or to chemical reaction with the hydrous silicate. The action is frequently complicated by the two last named phenomena.

It must be assumed that the addition of alkali produces a certain, probably very small amount of highly dispersed material approaching in its behavior the lyophile emulsoids. The portion of the clay assuming this state must, in the nature of the case, oppose the settling out of the granular material made mention of above. Hence in the separation of crystalline material from highly dispersed clay substance, it is necessary to use a much larger amount of water than with coarser clays. The phases of flocculation, deflocculation and re-flocculation occurring with increasing amounts of alkali are shown in the photograph of Fig. 1.

FIG. 1.



Deflocculation and coagulation of kaolin suspended in water.

The condition shown existed after allowing the tubes to stand for 12 hours. The material still in suspension is evidently of very great fineness, since all other particles must have settled out after so long a time. Where separation of the highly dispersed clay substance from the granular material such as quartz, feldspar, ilmenite, pyrite, biotite, mica, etc., is desired, the time of settling is of considerable importance, inasmuch as the particles are precipitated according to Stoke's law.

The deflocculated, alkaline suspension is immediately coagulated and precipitated by the addition of acids and salts, like aluminum sulphate, barium chloride, etc. The flocculating effect

appears to be a function of the valency of the cation since, for instance, the salts of aluminum are very much more effective than those of calcium, and the latter more so than potassium salts.

The facts stated above are applied industrially in improving the washing process employed in the purification of kaolins and in the so-called casting process. Up to the present time the washing of the kaolin from the crude rock mixture consisted in blunging up the material with water to a thin suspension and depositing the waste rock débris by causing the liquid to flow through settling troughs into basins where the finest granular matter was separated. The fact that the addition of alkali lowers the viscosity of the clay-water system and thus brings about a sharper and more prompt separation of granular and dispersed clay matter, caused Keppeler [1] to invent a process making use of this phenomenon, thus improving the washing process by securing a purer yield of clay substance. This process was first brought to the attention of the American industries by the late H. E. Ashley, who worked out in detail the principles involved.[2] The same principle was employed also by Count Schwerin [3] in his endosmose process in which deflocculation by means of alkali is followed by the deposition of the clay substance upon a metallic band which forms the positive electrode. The negatively charged clay particles are thus deposited by the electric current, and at the same time separated from the water. It has been shown that the electrical separation has no connection with the purification of the kaolin itself, since this is accomplished by the preliminary treatment with alkaline electrolytes.[4] These methods, though simplified, have been used by the Clay Products Laboratory of the Bureau of Standards [5] in the purification of several American kaolins and in the application of the principle in a kaolin washing plant of Eastern Pennsylvania, in 1914. The Bureau of Mines has employed the process in the purification of Georgia kaolins. There is every reason to believe that by means of such processes

[1] German Patent No. 201,987.

[2] Trans. American Ceramic Society, vol. 12, p. 768, Bureau of Standards' Technologic Paper No. 23.

[3] *Tonindustrie Ztg.*, **36**, 1283–85. Trans. English Ceramic Society, **12**, Part I, 36–65.

[4] Trans. American Ceramic Society, vol. 15, p. 338. Bureau of Standards' Technologic Paper No. 51.

[5] Technologic Paper No. 51.

it will be possible to treat American kaolins so that they can be utilized in the manufacture of the highest grades of porcelains.

The other industrial application of the deflocculation of clays is connected with the so-called casting process in which the mixture of kaolin, ball clay, feldspar and quartz, producing porcelain, with the simultaneous introduction of a small amount, usually 0.5 per cent. of a mixture of sodium carbonate and sodium silicate is made into a thick suspension with water. Here the addition of the alkaline reagents is effective in reducing the water content required to keep the suspension fluid. In fact, the amount of water present is not greater than that found in the same mixture in the plastic state, without the use of the electrolytes. The slip is poured into a plaster mold which absorbs water greedily, and hence causes the formation of a solid wall, conforming to the contours of the inside of the mold. According to the thickness of wall desired, the slip is left in the mold a shorter or a longer time, when the liquid still remaining is poured off. In this manner intricate shapes of clay ware can be readily produced. The process is used largely in the manufacture of sanitary ware, but has been extended to the making of such large and heavy articles as glass pots. The effect of varying amounts of the alkaline reagents upon different clays, the question of adsorption, the time factor, and a number of similar problems, offer a fruitful field of research in applied colloidal chemistry and which have received some attention in American technical literature.[6]

The effect of electrolytes upon clays in the plastic state as regards plasticity, drying shrinkage, strength, etc., is of an interesting character and has led to some useful discoveries, such as the prevention of drying cracks by the use of small amounts of sodium chloride or larger percentages of hydrated lime.

With reference to the effect of electrolytes in general, it might be stated that the presence of H ions is conducive to increased plasticity, while OH ions tend to reduce this quality. However, such phenomena as hydrolysis and adsorption may complicate the effects decidedly, and in the case of small additions we are undoubtedly dealing with very unstable equilibria. The effect of preheating clays, before fabrication, to temperatures as high as

[6] Kirk, **Trans. American Ceramic Society, 15,** p. 573. Bureau of Standards' Technologic Paper No. 51, Bureau of Mines, Technologic Paper No. 126.

500° C., upon the colloidal structure, has brought out information which may be useful in dealing with clays possessing an excessive tendency to shrink and crack in drying.

The examples stated tend to show that we are gradually mastering the phenomena, both chemical and physical, occurring in the heterogeneous rock mixture known as clay. Well-known general facts, such as the laws governing evaporation, have been found very useful in the control of the drying process and in rendering harmless salts tending to deposit on the surface of clay ware, as the sulphates of lime and magnesia, by the introduction of equivalent amounts of barium carbonate or hydroxide.

With reference to the burning of clays, the amount of theoretical and practical information is increasing steadily. We are informed as to the dehydration temperature range during which the kaolinite molecule, $Al_2O_3.2SiO_2.2H_2O$, loses its combined water. The decomposition proceeds most rapidly at 500° C. but the last of the chemically combined water is not expelled before 800° C. The increase in the specific volume of clay upon dehydration and its increased solubility in acids in this state have been well established. At 850° C. the exothermic reaction of clays first detected by Le Chatelier [7] has been confirmed repeatedly though opinions differ as to the reaction involved.

Reactions associated with the impurities combined in clay, especially carbon and the hydrocarbons, pyrites, and calcium carbonate, are sometimes of far-reaching consequence. That the complete oxidation of carbon at a low temperature, while the clay structure is still porous, is of the greatest importance for the successful firing of clay products has been clearly demonstrated by Edward Orton, Jr., in his classic researches.[8] It is not an exaggeration to state that the amount of money saved the manufacturers of clay products by means of this specific information amounts to a considerable number of millions of dollars.

Considerable work has been done also in the study of the stages of incipient and complete vitrification of clays in firing. It is now generally understood that the contraction and consequent decrease in porosity is due to the action of surface tension, tending to contract the mass, and is made possible by the softening

[7] *Comptes Rendu*, 104, pp. 1443, 1517.

[8] The Rôle Played by Iron in the Burning of Clays. Trans. American Ceramic Society, vol. v, p. 377.

due to the effect of the fluxes. Interesting questions have arisen with reference to the speed of vitrification at different temperatures, the time effect at constant temperatures, etc., which have an important bearing on the control of the firing process. At the same time the question of composite eutectics of such complex systems demands consideration as well as that relating to the

FIG. 2.

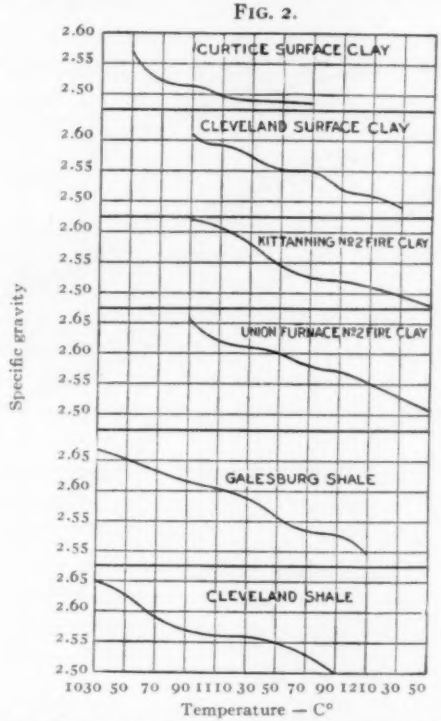
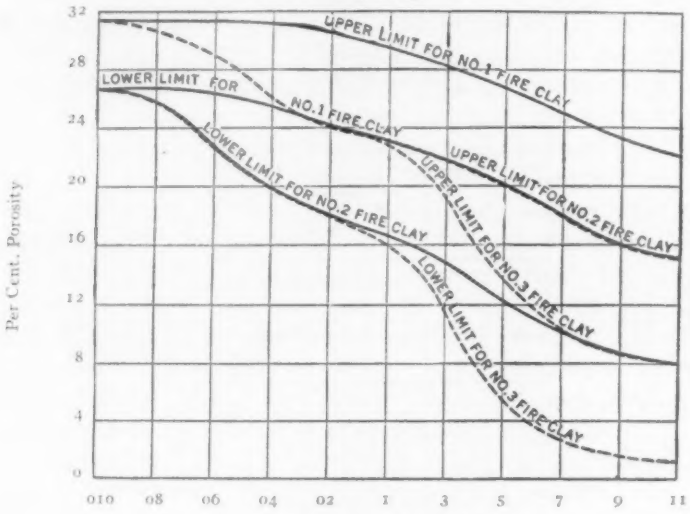


Diagram showing the continued decrease in the specific gravity of clays fired to temperatures above their vitrification point.

viscosity at different temperatures. These problems are very much complicated by the fact that we are dealing here with physically heterogeneous systems which are far from equilibrium. Even overburned clays, approaching fusion, are still undergoing changes due to solution and interaction as is shown by the curve of Fig. 2, in which the specific gravities of typical clays are plotted for increasing temperatures. It will be noted that the specific volumes are still undergoing a decided increase and that they will reach constancy only upon complete fusion.

In the study of clays for the purpose of estimating their technical suitability, the most important relation is that between porosity and firing temperature under established firing conditions, such that the temperature increase does not exceed 25° C. per hour. A diagram illustrating this relation is shown in Fig. 3, and this method of judging the quality of clays is of great value. It was first proposed by Purdy[9] and makes possible a sharp

FIG. 3.



Purdy's porosity--temperature diagram used in classification of fire clays.

differentiation between easily and difficultly vitrifying clays, and between low- and high-grade materials.

The explanation of the fusion phenomena entering into the discussion of vitrification has received powerful support from the theoretical investigations of the Geophysical Laboratory at Washington, but the field to a very large extent is far from being covered in its entirety. Through the study of the fusion and deformation of the more complex systems of silicates it will finally be possible to map out with a good deal of accuracy their behavior under industrial conditions.

The viscosity of the silicates at the higher temperatures, but below their fusing points, is technically of extreme importance.

[9] Illinois Geolog. Survey, Bull. No. 9, p. 256.

If it were not for this property, it would be impossible to manufacture porcelain or other vitrified products. The evaluation of viscosity related to temperature is very essential in ceramic as well as metallurgical problems, where the deformation of refractories at high temperatures is sometimes of considerable practical significance. Mellor,[10] in the course of recent studies as well as others before him, has found it desirable to make a particular study of the decrease of viscosity of clays with temperature. The last-named investigator, in fact, has derived a mathematical relation between the temperature and the load in pounds per square inch, required to deform the materials which may be expressed by the equation:

$T = Ce^{-kw}$, where

T = deformation temperature in °C.,

C = deformation temperature in °C., without load,

k = constant,

w = load in pounds per square inch, and e = exponential constant. A number of other physical constants, such as the coefficient of expansion, the thermal conductivity, etc., have been determined for the several classes of materials with more or less accuracy.

One of the most potent tools in the study of vitrified or fused silicates has been found in the application of petrographic-microscopic methods. For instance, it is now possible by means of microscopic data to determine the composition of a porcelain as well as the heat treatment it has received. Similarly, we are in position to state whether silica refractories, so largely used now in the metallurgical industries and in by-product coke ovens, have been carried to the proper temperature, a point of great significance which may have an important bearing upon the permanency of costly furnace structures. Thus, we have in the illustration of Fig. 4 a microphotograph of a section of Japanese porcelain, showing the formation of crystalline sillimanite produced by the decomposition of the clay substance, and the solution of the quartz grains in the fused feldspathic magma. The work of Klein [11] relating to the microstructure of porcelain has proven of great value in bringing out the real facts concerning the vitrification process of feldspar—clay substance—quartz mixtures.

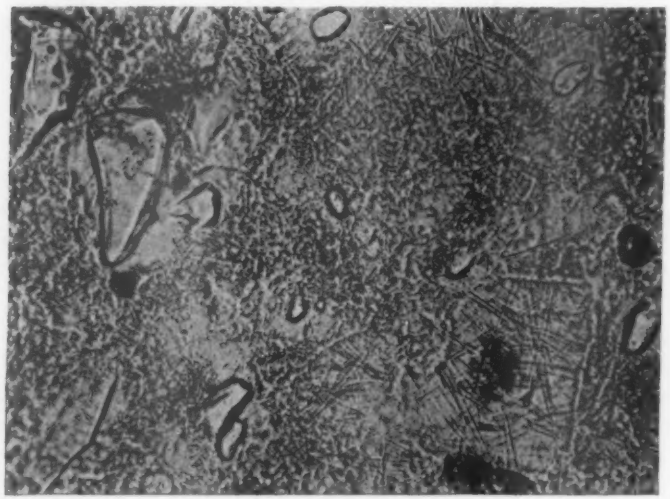
[10] Trans. English Ceramic Society, vol. xv, Part I, p. 117.

[11] Bureau of Standards, Tech. Paper No. 80.

Again, Fig. 5 illustrates the proper structure of a silica brick with but a small amount of unchanged quartz, most of this mineral having been transformed to cristobalite and tridymite. The deeply-fissured fragments, originally quartz, are characteristic of a well-burned product. Microscopic research, with all of its accessory technics, is to-day an indispensable adjunct of a ceramic laboratory.

During the firing process the character of the combustion gases, whether oxidizing or reducing, is of importance with refer-

FIG. 4.



Micro-section (by Klein) showing structure of Japanese porcelain.

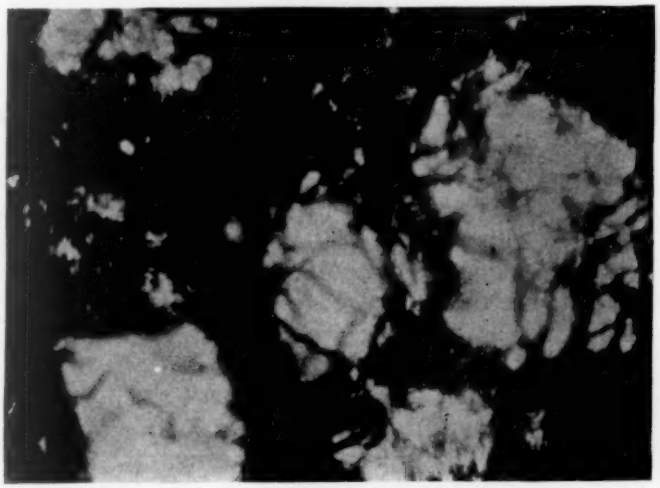
ence to the ultimate color of the ware, and hence requires careful consideration. This applies especially to products coated with colored glazes, since it is not immaterial whether we produce, for instance, the green color of cupric or the red of cuprous oxide. Similar conditions prevail as regards the ever-present ferric oxide, with reference to the formation of ferrous or of magnetic oxide. In our modern clay working plants much skill is now being shown in the production of various colored face bricks by the use of oxidizing or reducing kiln atmospheres.

Theoretical speculations as to whether the silicates here under discussion are or are not ionized, when being vitrified, have not

been without experimental evidence. Indeed, it appears to be true that these mineral mixtures show ionic conduction and such associated phenomena as polarization.

Interesting data have also been obtained in connection with the determination of the di-electric strength of vitrified bodies, and it has been found that there is a decided drop in the resistance of porcelain at temperatures as low as 200° C.[12] The testing of high tension insulators has become a well-established practice in electrical porcelain works.

FIG. 5.



Micro-section (by Klein) of well burned silica-brick.

The application of pyrometry in the ceramic industries has been quite extensive. The platinum platinum-rhodium thermo-couple and with it the high resistance millivoltmeter are used in hundreds of works for controlling kiln temperature. Base metal couples are likewise employed in large numbers for lower temperatures. The pyrometric cones devised by Seger and manufactured in this country by Orton afford inexpensive means of fixing the finishing point of kilns, even though they do not measure temperatures. Since they are composed of silicate mixtures, their softening point expresses the effect of both time and temperature.

[12] Trans. American Ceramic Society, 13, p. 469.

The physical properties of structural clay products, refractories, etc., have not yet been studied as thoroughly as the importance of the subject deserves. Certain classes of materials have received practically no attention. It would be well worth while if more consideration were given to this subject in the curriculum of the architectural and engineering departments of our colleges. In this connection both the intrinsic strength of the materials for different degrees of porosity and the strength of the fabricated products must be treated. In the case of building bricks a good deal of testing has been done both upon individual and built-up specimens, especially at the Watertown Arsenal under the direction of Mr. J. E. Howard, but the data has not been correlated for the different types of material. An attempt to do this has been made by the writer,[12a] but the available material is entirely too meagre in volume. Not only the mechanical qualities expressed by the compressive and transverse strength, the modulus of elasticity, resistance to shear, resistance to sudden temperature changes, and the thermal properties, but also the durability and resistance to weathering are of vital importance. In fact, the latter quality should receive most careful attention, considering the fact that hundreds of millions of dollars are being expended in the use of these products. Obviously, this applies to stone and concrete as well.

Of late efforts have been made to replace the time consuming and laborious freezing test, largely used in this connection, by accelerated tests, of which the most promising is the Brard process consisting in immersing the specimens in a boiling concentrated solution of sodium sulphate (Glauber's Salt) and drying them in order that the salt may crystallize. This test is sharp and decisive, but severe. There should be no difficulty, however, in modifying it, as has been suggested in recent work.[13]

This brief résumé of the investigative activities in connection with the ceramic industries indicates that we need not apologize for the part taken by American ceramists in the work covered by this field. To no small extent do we owe this condition to the technical work offered in ceramics by several universities and colleges, and to the agency of the American Ceramic Society.

[12a] International Engineering Congress, San Francisco, 1915.
[13] Howat, Trans. American Cer. Soc., 17, p. 249.

THE RAW MATERIALS OF THE UNITED STATES.

From the industrial standpoint, clays may be roughly divided into seven classes:

1. Primary kaolins, usually white burning, very refractory, and of low plasticity and strength.

2. Plastic kaolins, not as white burning as primary clays. May be very plastic.

3. Clays of the fire-clay type, ranging from materials of high refractories to those inferior in this respect. Certain highly refractory clays, called flint clays, are almost lacking in plasticity. Very plastic clays, called ball or bond clays.

4. Shales. Fine-grained, hard clays, showing well-defined cleavage and often slate-like in appearance. They differ widely as to composition. Many ferruginous shales are sources of the best paving brick. Shales, as a rule, are uniform over comparatively large areas, and hence have great industrial importance.

5. Alluvial clays. Of recent geological origin and found principally in old and new river valleys. Vary widely in composition and physical behavior, from clays of excellent plasticity to very sandy materials. As a rule, unsuitable for paving brick. Usually burn to a red color.

6. Glacial clays. Heterogeneous mixtures of clay with various rock débris. Frequently calcareous, causing clay to burn to a cream or buff color. As a class, difficult to work and hence suitable only for rude products.

7. Loess clays. Wind-blown deposits, usually silicious and hence of low plasticity. Used only for common bricks.

The United States is not deficient in any of the types of clay, although the distribution, of course, is not uniform, so that many states are lacking entirely in certain kinds of raw material. This question will be taken up in connection with the discussion of the several industries.

THE BRICK INDUSTRIES.

The manufacture of common building bricks is extended practically over the entire country, though the materials available vary widely. Thus New York draws upon the alluvial clays of the Hudson Valley, Philadelphia upon the surface clays and to a limited extent upon shales, Chicago upon calcareous, glacial

clays, New Orleans upon extremely sandy alluvial clays and a large part of the South upon characteristic red surface clays, sticky in character, while Pennsylvania, Ohio, Indiana, southern Illinois, Iowa, Missouri, Kansas, Oklahoma, Kentucky, Arkansas, Alabama, Washington and Oregon have available great deposits of shale and in connection with the carboniferous series of rocks also plastic fire-clays of the number two grade. Certain states like Florida and Michigan are rather poor in clays possessing good working qualities. The glacial clays of Wisconsin, Minnesota and North Dakota frequently offer considerable difficulty in brick manufacture. From this it is evident that the quality of the bricks must vary considerably in different localities. The hard-burned, vitrified building brick of Ohio and Pennsylvania is an entirely different product from that obtainable in Louisiana or in the Chicago district. It is evident, therefore, that it is a difficult matter to establish specifications for building brick which are fair to all the materials, when we are dealing with variations in compressive strength from 20,000 to 1000 pounds per square inch and in water absorption from 1 or 2 to 30 per cent.

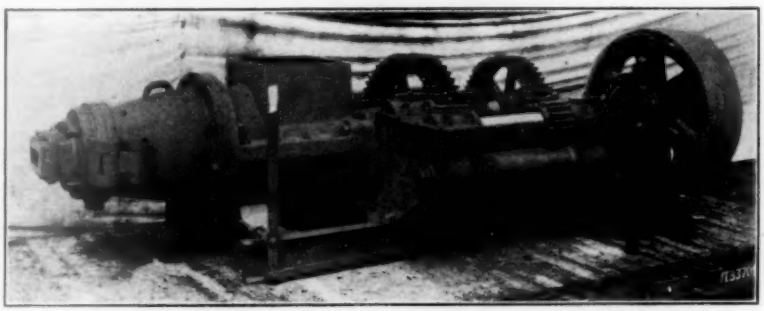
The old art of brick-making has undergone considerable changes within the last 20 years. The hand-molding process has been largely replaced by machine methods, employing either the soft clay, stiff clay or dry-press method. The American brick-making machines, both as to capacity and construction, are probably the superior of any in the world. The stiff clay machines predominate at the present time, although it is necessary to resort to the use of the soft-clay machine or dry-presses in dealing with clays deficient in plasticity. Fig. 6 illustrates a high-grade, stiff-clay machine, which forces the clay through a die in the form of a column which is cut into bricks by means of an ingenious automatic apparatus, employing moving wires for this purpose. In Fig. 7 a modern heavy dry-pressing machine is shown. The capacities of the stiff-clay machines are very large; the production of 100,000 bricks per unit and per day of 10 hours is not uncommon.

No longer is the sun's heat called upon to dry the molded bricks, but dryers artificially heated are employed for this purpose. In these the bricks are placed on cars and the latter run through heated tunnels. Two systems of dryers are in use, the continuous and the periodic. In the former the cars are constantly being

discharged and replaced, the temperature and humidity conditions being about the same all of the time.

Roughly three zones may be distinguished in the operation of these dryers—the steaming, the evaporating and the heating zone. In the first the wet bricks must be warmed up without undergoing any appreciable evaporation; in the second, increasing evaporation is permitted as the cars travel along, due to the higher temperature and lower humidity, and in the third, the last portion of the water is expelled and the dry bricks heated somewhat below the temperature of the incoming hot air. The air

FIG. 6.

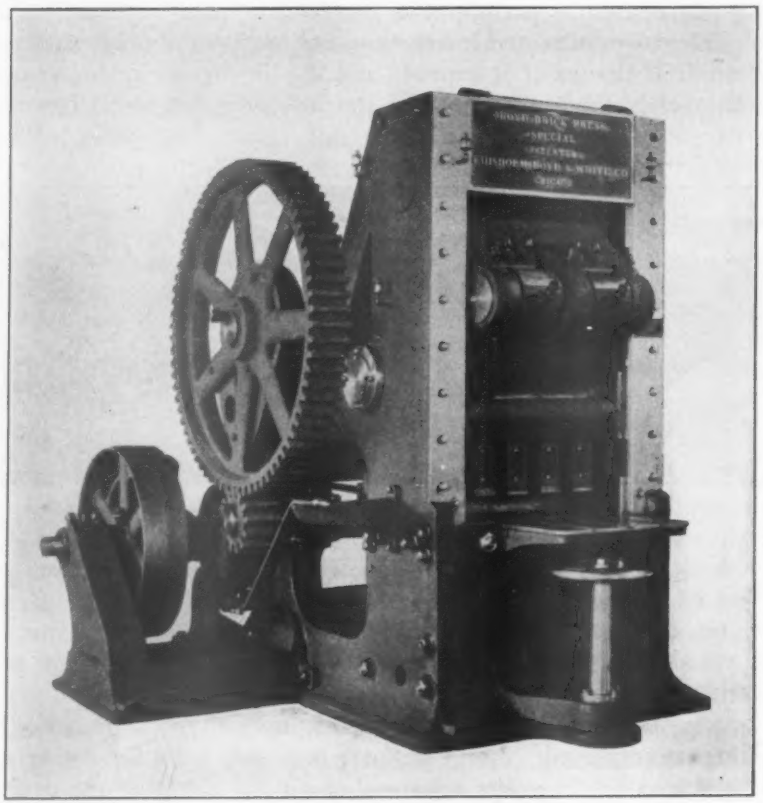


Auger brick machine.

and vapor pass through the tunnels in the direction opposite to that of the cars. The heat required for the evaporation of the water is obtained either from cooling kilns, steam pipes, metal-covered flues, heated from separate furnaces, or even from the combustion gases. The heat from cooling kilns is used most largely and has proven an economic necessity where periodic kilns are employed. Large fans are necessary, both for removing the heated air from the kilns and the moist air from the dryer. This type of dryer is the most economical when operated properly, but is not well adapted for operating with sensitive clays, having a tendency to check and crack in drying. Also the dryer is afflicted with certain inherent defects as unequal heat distribution due to the horizontal direction of the air current. For this reason recent developments have brought about certain changes, especially in carrying the steaming temperature to a very much higher point and in the use of smaller fans for cross circulation.

The second type of tunnel dryer is periodic in operation, a tunnel being filled with the loaded cars, after which it is closed and heating begun. The atmosphere soon becomes saturated with steam and at the same time the temperature rises, thus preparing

FIG. 7.



View of dry press brick machine.

the ware for the evaporation process which is to follow. Then the small stacks, of which there are a number on top of the tunnel, are gradually opened and the drying allowed to begin. This periodic system permits of complete control of the drying and hence even the most sensitive clays can be carried through this operation without harm.

The burning of the bricks is of course the most important part of the process. There are used for this purpose the old-fashioned clamp kiln, the down-draft and the continuous kiln. A new continuous type of kiln, the tunnel kiln, is also appearing on the market. For mass production the clamp kiln is holding its own, especially because it is adapted admirably for mechanical setting where units of 500, or even 1000, bricks are taken from the dryer cars and set in position in the kiln. Similarly, the burned bricks are removed from the kiln in the same fashion. This modern phase of brick handling is known as the Penfield system. The clamp kiln, so familiar to us, suffers under the great disadvantage of producing a considerable percentage of soft-burned bricks, a difficulty almost impossible to overcome. It is this defect and not lack of fuel economy which is leading to the gradual displacement of this type. This is especially true in localities where there is a well-established demand for a hard, vitrified product. Still, the clamp kiln will hold its own for a long time to come owing to its simplicity and cheapness of construction and the ease of setting and removing the ware which are economic advantages of importance.

The down-draft kilns, both square and round, are used wherever a uniformly hard product is required, and they are indispensable in the manufacture of paving brick. Lately also, the use of producer gas has been introduced in connection with down-draft kilns illustrated in Fig. 8. Considered from the standpoint of heat efficiency, all periodic kilns, whether of the old-fashioned clamp or the down-draft type, are exceedingly wasteful. It has been determined that even in the best operated periodic kilns not more than 25 per cent. of the fuel is actually utilized for the burning of bricks. This condition is still more strikingly illustrated in the case of pottery kilns where the heat actually used is not more than 5 per cent. of that introduced. The question of fuel economy is, therefore, becoming a question not only of importance with reference to these particular industries but also to the country at large, since any kind of fuel waste is against public policy. It must be confessed that in the question of fuel economy we have been negligent and that in this respect our methods of burning clay products are inferior to those of Europe. However, there is a decided current at the present time towards the replacement of the periodic by continuous kilns.

The latter, first invented by Hoffmann and Licht, embody the principle of utilizing both the heat of the cooling ware and the heat contained in the products of combustion, thus making possible almost complete regeneration. These kilns are in the form of an endless tunnel, oblong in form, so that there are two long tunnels, side by side, connected at the ends. Two forms of kilns are to be distinguished, the one being essentially a continuous, uninterrupted tunnel, the other a series of chambers, built side by side and connecting with each other. The first type is intended

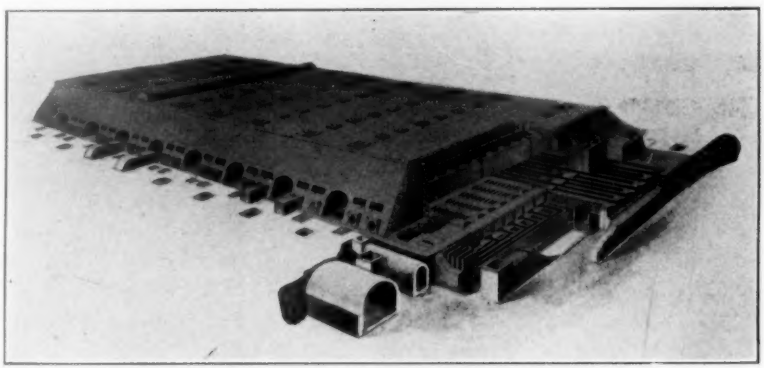
FIG. 8.

Down-draft kilns fired with producer gas.

primarily to be fired from the openings in the top, using slack as fuel; the second one, is especially adapted to the use of producer gas and was first introduced by G. Mendheim and his associates. The top firing with small coal has not found great favor among American manufacturers. For this reason, the continuous principle was partially sacrificed by firing both through the charging doors of the kiln and in the usual way through the openings in the arch. This system is represented by a number of installations and is known as the Haigh Kiln.

Since the chamber type of the continuous kiln is well suited for producer-gas firing, it is finding application especially in the burning of facing and paving bricks. The first successful kiln of this kind was that of Youngren, fired on one side of the chamber, which was later improved by Rodgers and others and has been found very successful. The gas is usually introduced through flues in the bottom of the kiln. More recently the double-fired chamber of the Richardson kiln, having gas ports on both sides, has been introduced and is of considerable promise. The construction of the last-named kiln is illustrated in the view of Fig. 9.

FIG. 9.

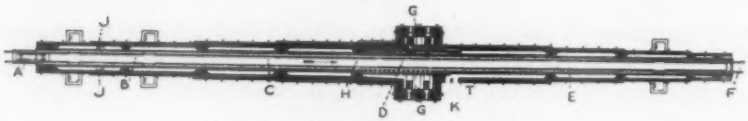


The Richardson gas-fired continuous kiln.

The tunnel type of kiln has of late received considerable attention and is represented by two systems. In the first, the bricks are loaded on cars which are gradually pulled through a tunnel, having furnaces or gas ports on both sides along the middle section. The cars obviously must be provided with platforms, built up of refractory material in order to protect the running gear which is cooled by a current of air. The tunnel is thus divided into the firing chamber and a channel containing the track and iron work of the cars. Leakage of gases is prevented by longitudinal sand seals on both sides of the car. The direction of the gases is opposite to that of the cars. Thus the heat of the combustion gases is used to preheat the ware and the fired product gives off its heat to the air used in combustion The second feature is worked out more satisfactorily when pro-

ducer gas is used as fuel. This system of the tunnel kiln is quite old in its inception and the first European patent was probably issued as early as 1840. The best known constructions are the Faugeron kiln in Europe and the Didier-March kiln in the United States. The plan of the latter kiln is given in the diagram of

FIG. 10.



Plan of tunnel kiln used for burning brick.

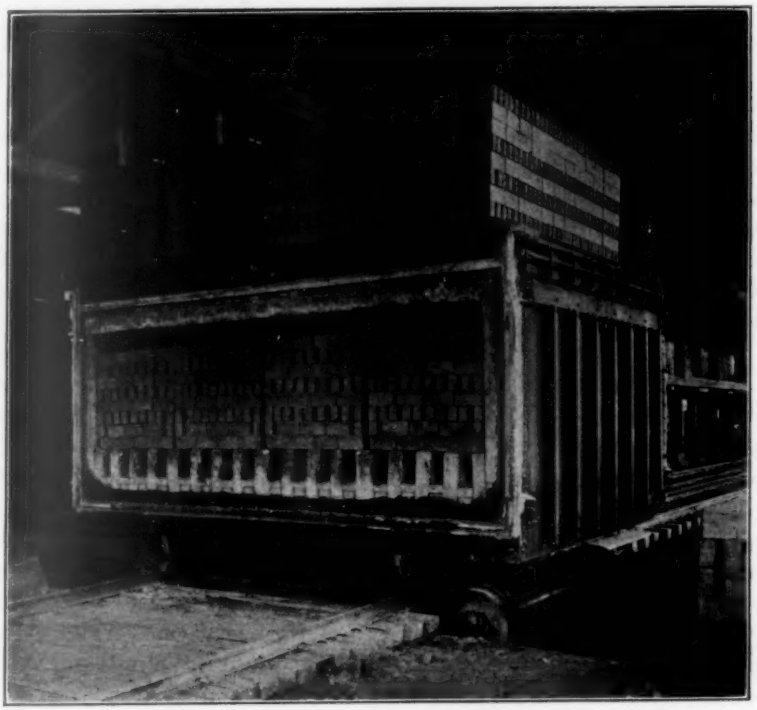
FIG. 11.

View showing cars loaded with brick about to enter tunnel kiln.

Fig. 10. It will be noted that by the use of flues separated from the tunnel by means of perforated walls, a kind of serpentine motion is imparted to the flames which is caused to pass from the tunnel to the flue, where it again changes its direction back to the tunnel. The photograph of Fig. 11 shows cars loaded with bricks about to enter the kiln.

The second system of the tunnel kiln type for burning bricks is of American origin and was invented by Alexander Scott. It is based on a most ingenious idea, namely that of dividing the tunnel kiln in sections and putting them on wheels so that the kiln is made up of a series of movable chambers. The kiln sec-

FIG. 12.



View showing unit of Scott tunnel kiln.

tions thus form a train composed, say, of 13 or 14 such cars. As soon as a chamber has been fired and cooled it is removed and a section containing a fresh charge attached to the other end of the train. The construction of the cars is illustrated by the photograph of Fig. 12. The firing is done by means of producer gas, movable connections being used which attach to four cars in the middle of the series.

All tunnel kilns have in common, not only the fuel economy inherent in the principle, but they also render the placing of the ware and its removal much easier and cheaper.

The common brick industry has suffered somewhat from competition with concrete. The manufacture of face brick, on the other hand, has established itself more and more firmly by offering to the building public, not only a large variety of colors and shades, but also by producing pleasing rough textures, known as texture or tapestry brick and other trade names.

Both for the purpose of reducing the cost of the laying up of walls and of providing air spaces which are desirable for apparent reasons, there has been a remarkable growth in the manufacture of hollow tiles, using both vertical and horizontal webs. In addition special shapes, such as the Dennison interlocking tile, Fig. 13, have been designed and have proven very successful. Retaining the idea of the brick unit another kind of tile has been developed, the Fiske type, which makes possible the use of the artistic effects of brick.

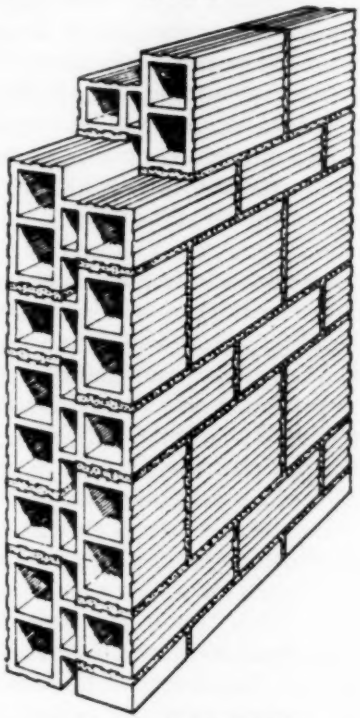
An important development of the brick industry is the manufacture of paving blocks which has kept pace with the expansion of the network of paved streets and roads. Realizing that the success of brick-paved streets is as much or more dependent upon a proper method of construction than upon quality of the material, this branch of the industries has made consistent and effective efforts towards careful and thorough construction. Of late, monolithic brick pavements in which the blocks are laid in wet concrete have gained in favor. The largest producers of paving blocks are the states of Ohio, Pennsylvania, West Virginia, Indiana, Illinois, Kentucky, Kansas, Washington, Oklahoma, Alabama, Tennessee and Oregon. The geographical area of shales suitable for this purpose is practically limited to the states mentioned, owing to the rigid requirements governing paving blocks.[14] The adoption of a standard rattler test has made it practically impossible to market anything but products of the highest grade.

In the field of fire-proofing, in the protection of steel columns and girders of sky-scrapers, clay products must now compete with concrete, gypsum and other materials. As a result the volume of this business has somewhat decreased. This loss has been compensated for by the increased production of hollow tiles, conduits and similar products.

[14] Yearbook Am. Soc. for Testing Materials, p. 396.

The sewer pipe industry also has felt the competition of concrete, especially in the larger sizes, but it has managed to hold its own. The adoption of segmental sewers has been found an effective means of meeting the new competition.

FIG. 13.



Wall section of interlocking tiles.

THE REFRACTORIES INDUSTRIES.

Refractory materials are indispensable in the practice of the metallurgical arts, in the melting of glass, the clinkering of cement, in the ceramic firing processes and last but not least, in the generation of steam. The principal types are the clay, silica, magnesite and aluminous refractories.

Clay Refractories.—For the sake of convenience three kinds of clay materials may be recognized in this connection, called for convenience, No. 1, No. 2, and No. 3 refractories. The greatest heat resistance is shown by those clays corresponding most closely

to the theoretical kaolinite composition, 46.3 per cent. silica, 39.8 per cent. alumina and 13.9 per cent. chemical water, which upon heating becomes 53.8 per cent. silica, and 46.2 per cent. alumina, and by the so-called bauxitic clays. The latter are admixed with some bauxite which may raise the alumina content as high as 60 per cent. (in the hydrous state). The increased amount of alumina brings about a decided increase in the refractoriness of the material. Clay of the purest type possible, kaolinite, has a softening temperature corresponding to the melting point of platinum, 1755° C., or expressed in standard pyrometric cones, to cone No. 35. Owing to the greater or smaller amount of impurities, such as silica in the form of quartz, feldspar, lime and magnesia, this softening temperature is hardly ever realized. A softening temperature of 1725° C. is about as high as is reached by high-class fire-clays, such as the flint clays. Clays containing bauxite may soften at temperatures as high as 1800° C. A high grade of No. 1 fire-clay should not soften below cone 31 or approximately 1685° C. This point, therefore, would be about the dividing line between No. 1 and No. 2 fire-clays, though others place the limit considerably lower. The division line between the No. 2 and the No. 3 clay refractories would be at cone 28, or roughly 1635° C. Clays softening below this limit might be classed as No. 3 refractories. Although this arbitrary classification may be considered too exacting by some, it has worked out quite satisfactorily in a clay-testing practice extending over a number of years.

Fire-clays may also be divided into two types of clays according to whether they are plastic and dense burning at comparatively low temperatures, say, around 1200° C., or whether they are open burning, *i.e.*, retain their porosity within this temperature region. The clays of the second class are also, as a rule, less plastic than those of the first. The characteristic behavior of the denser burning clays is due, of course, to their higher content of fluxes.

Silicious fire-clays, that is clays with a silica content above 75 per cent., possess a lower softening temperature than the highest grade fire-clays and are influenced more potently by the presence of fluxes. It is more important that a silicious fire-clay be low in the basic constituents, iron oxide, lime, magnesia, potash and soda than an aluminous one since the lowering of the soften-

ing point is more marked. On the other hand, silicious clays have a decided advantage over the average clay fire-brick in that they are not subject to shrinkage in use and are able to carry considerable loads at furnace temperatures without showing any appreciable deformation. They are able to stand up well at temperatures not far removed from their ultimate softening point while clay fire-brick cannot safely be carried to temperatures within 150° C. below the deformation point. At the same time, clay fire-bricks show considerable contraction and soften sufficiently even at temperatures as low as 1400–1450° C. to render them unable to carry loads greater than 10 pounds per square inch. This statement needs to be modified, however, in that high clay fire-bricks may be manufactured by the use of highly calcined No. 1 clay (grog) and by high burning of the material so that the contraction is very small and the load-carrying power quite high. In doing this the contraction of part of the clay is practically completed in the calcination and in the burning of the bricks, so that but a small shrinkage can take place later. At the same time the compact structure is able to resist the usual pressure conditions in furnaces satisfactorily. Such a process of manufacture is expensive. All non-silicious clays tend to shrink in burning, due in part to the colloidal contraction and in part to the effect of the fluxes which are active in lowering the viscosity of the clay, thus bringing about a gradual liquefaction. In silicious clays this shrinkage is practically eliminated, not only on account of the much smaller amount of clay substance present, but also on account of the volume increase of the quartz in its transformation to cristobalite and tridymite. This volume change may be great enough to cause expansion of the brick upon burning rather than contraction. The high silica content, however, brings with it certain disadvantages such as inability to withstand sudden temperature changes, which does not apply to clay bricks.

Silica Refractories.—These are principally produced from a mixture of ground quartzite and lime paste, so that in the fired product the silica content may be from 94 to 97 per cent., and that of the lime about 2 per cent. The firing of the dried bricks is carried to quite a high temperature, usually to above 1500° C. In the burning the lime bond tends to form a mono-calcium silicate and the quartz is transformed to cristobalite, an intermediate crystalline modification of silica. This transformation

is coincident with the expansion of the brick, usually three-eighths inch to seven-sixteenths inch per linear foot over the mold measurements.

This linear expansion may be used as the criterion of the proper degree of burning, though it is by no means completed in the kiln but continues upon heating the bricks in use. The cristobalite, constituting about 80 per cent. of the finished silica brick, is not the stable phase at the temperatures involved but is further transformed to tridymite. Smaller quantities of this crystalline modification of silica are usually found in silica brick and some time after the latter are in use, provided the temperature is sufficiently high, it becomes the predominating constituent. Thus in open-hearth or glass furnaces the silica brick structure consists mainly of tridymite.

Although the refractoriness of silica refractories is lower than that of the high-grade clay bricks, corresponding to about 1700° C., their effective, useful temperature range is very extensive. Their rigidity and freedom form deformation at high temperatures, say 1600° C., is superior to that of clay refractories. Failure as a rule occurs quickly near the softening temperature and there is no long interval during which serious deformation may occur.

The one difficulty associated with the use of silica brick is their inability to stand up well under conditions of sudden heating and cooling. When subjected to such treatment they tend to spall and break down, especially if cooled below 600° C. Silica bricks are made also in which clay is introduced as a bond in place of the lime. This class of ware resembles the silicious fire-clays in behavior. As a rule they are not quite as satisfactory as the lime-bounded materials, though they are somewhat more resistant to sudden temperature changes.

Aluminous Refractories.—The use of bauxite and mixtures of bauxite and fire-clay is assuming larger proportions than it has in the past. This is particularly true at the present time when, due to the scarcity of magnesite, a substitute for the latter is being sought. From accounts which have been obtained it seems that it is possible to use refractories of this type successfully for purposes where magnesia seemed indispensable. The hydrous bauxite ores usually are impure, containing as a rule, 5 to 6 or more per cent. of ferric oxide. This applies to most American

bauxites. The melting point of pure alumina is about 2049° C. but that of bauxite does not as a rule exceed 1820° C. A very high shrinkage upon heating is characteristic of bauxites and hence it is important that as large a part of the material as possible be previously calcined. Unless this is done and the calcination carried to a high temperature the shrinkage of the product in use will be so high as to render it very unsatisfactory. Bauxite tends to contract also under pressure at furnace temperatures and hence is not so well adapted for uses where severe load conditions prevail. Owing to the feebly plastic nature of bauxite, bricks consisting of calcined and raw bauxite are rarely made. Usually a good fire-clay is employed to bond together the calcined bauxite. This naturally reduces the refractoriness of the mixture so that bauxite-clay fire-bricks do not, as a rule, possess a softening temperature above 1800° C. Bricks of this type are sold on the basis of the alumina content.

Greater refractoriness can of course be reached by the use of refined bauxite from which a large part of the iron oxide has been eliminated by chemical treatment.

Alumina is also an important constituent of refractory porcelain such as is used for pyrometer tubes, the so-called Marquardt porcelain. Here a considerable amount of alumina, previously calcined together with some feldspar, is introduced as the non-plastic portion of the mixture which in addition contains more feldspar and plastic kaolin. The fact might be mentioned that Marquardt porcelain of good quality has been produced by the Pittsburgh laboratory of the Bureau of Standards, covered both with a bright and a matt glaze.

Magnesia Refractories.—The magnesite products represent typical basic refractories. Two kinds of magnesite are to be distinguished, rocks approaching pure magnesite in composition such as the Grecian and California materials and the impure ones, containing from 3 to 8 per cent. ferric oxide and more or less silica, of which the Austrian magnesite is characteristic. The melting point of pure magnesia is very high, about 2800° C., but that of magnesite brick rarely exceeds 2170° C. Owing to the extreme heat resistance of the material and its great shrinkage, about 50 per cent., by volume, pure magnesite is not suitable for refractory purposes since it would be exceedingly difficult to reduce it to practically constant volume, while owing to the

fluxing action of the ferric oxide in the impure material the latter is more easily compacted.

The calcination of the magnesite is very important and in Europe it is conducted in shaft kilns working with forced draft. Rotary kilns would be well suited for this purpose. The dead burned magnesite, after having been crushed, is then intimately mixed with some low-burned magnesite, moistened with water and shaped into bricks under considerable pressure. The soft-burned magnesite functions as the cementing material. The bricks are then dried and burned in kilns to a high temperature. Magnesite bricks, owing to their basic nature and high heat resisting quality form a valuable refractory. The shortage of magnesite due to the European war conditions has made it necessary to look about for substitutes. In many cases bauxite materials have been found very satisfactory and it has been reported from several sources that this material has been permanently adopted. Dolomite has also been used as a substitute. For this purpose impure dolomite can only be used as it is necessary to "dead burn" the material as much as possible before attempting to make it either into bricks or to tamp furnace bottoms with it. A fairly high content of iron oxide is to be preferred, as in the case of magnesite and the calcination temperature should be carried as high as possible. Attempts have been made also to coat the crushed dolomite with a pulverized slag suspension in water so that upon burning a protective coating would be formed on the surface. The calcined dolomite, crushed to the desired fineness, is then mixed with hot tar as soon as possible and molded into bricks. These then must be burned again in order to remove the tar and bring about some consolidation of the particles. For tamping tar likewise is used as the bonding material. Dolomite material of this sort invariably slakes upon standing in the air. In spite of this difficulty it has been used to a considerable extent in European practice for many years.

In connection with the development of the by-product coke oven silica refractories are of the utmost value, since they furnish the bulk of the material used. Poor quality of the bricks and blocks or of the silica mortar used would be disastrous to the complicated and expensive structures used in this industry.

The European war has had some effect upon the refractories industries employing very plastic fire-clays for bonding together

grains of calcined or other non-plastic material. This applies especially to the makers of glass pots and similar accessories used in the glass industry and to the manufacturers of graphite crucibles. The bond clays formerly employed to a large extent were the German clays from Gross Almerode and Klingenberg, respectively. The situation has been met very successfully by

FIG. 14.

Covered glass pots.

the glass pot-makers and somewhat less so by the crucible people by using American clays. The reluctance of some manufacturers to use mixtures of several domestic clays in place of one clay has caused some delay in making progress. Since in the United States we have a considerable variety of refractory bond clays [15] there is no inherent reason why the clays formerly imported should not be replaced by American materials. In Fig. 14 some examples of glass pots made entirely from American raw materials are presented.

[15] Bureau of Standards, Tech. Paper No. 79.

ARCHITECTURAL TERRA COTTA AND TILES.

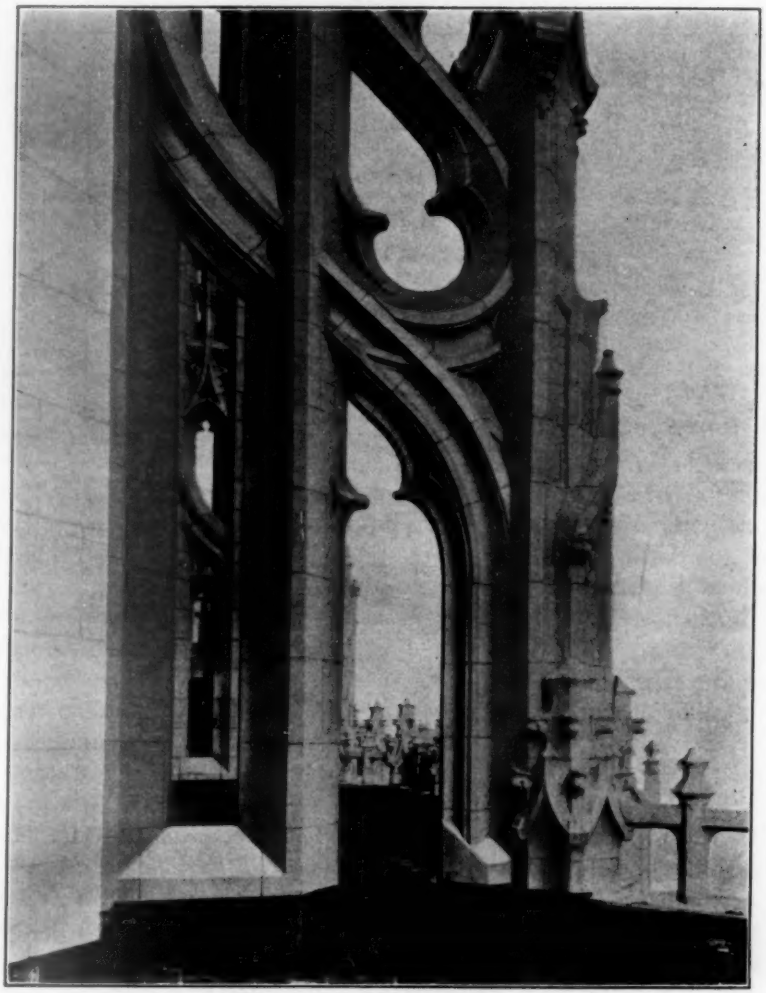
It is not perhaps realized that our large cities are rapidly becoming examples of burned clay architecture. The excellent frost and weather resistance of terra cotta, its fireproof character and strength, the readiness with which it can be made to assume any shape, color and texture, together with its comparative cheapness have caused it to become a largely used building material. This development is strictly American since nowhere else has architectural terra cotta been developed to such a remarkable extent. In meeting the demands of the architect the American terra cotta industry has made great achievements both from the artistic and the technical standpoint. Fig. 15 shows a detail view of the terra cotta construction of the Woolworth building, New York, a city whose sky line may be said to represent almost entirely a characteristic combination of steel and terra cotta. Similar artistic and technical progress has also been made with reference to interior decoration by means of tiles both for walls and floors. From the utilitarian standpoint, that of attaining practical aseptic conditions, maximum amount of reflected light, etc., the use of plain, glazed tiles and glazed bricks in public buildings, is rapidly increasing.

THE POTTERY INDUSTRIES.

The pottery made in the United States at the present time may be said to consist of the following types: Stoneware, majolica, white ware, and porcelain. The old-fashioned stoneware pottery, such as crocks, jugs, etc., has shown a great drop as regards output and appears to be approaching extinction. It has in part been replaced by modern developments in the production of chemical stoneware, formerly a European specialty, which is now experiencing a rapid growth in the United States. This development has reached such a point that the future will probably see but little importation of ware of this kind. The skill shown by American makers in this branch of industry is illustrated by the photographs of illustrations 16 and 17. The rapidity with which the manufacture of chemical stoneware has met the recent extraordinary demands of the chemical industries is surprising considering the fact that a large proportion of this kind of ware was formerly imported from Europe. This fact

calls attention to the close coördination between widely different industrial fields, in this case the clay and the chemical industries,

FIG. 15.

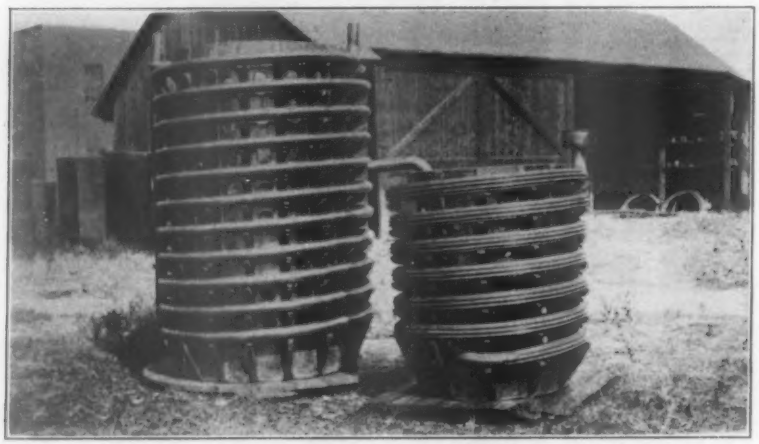


Detail of difficult terra-cotta construction.

which is necessary if we are to be in a state of true industrial preparedness.

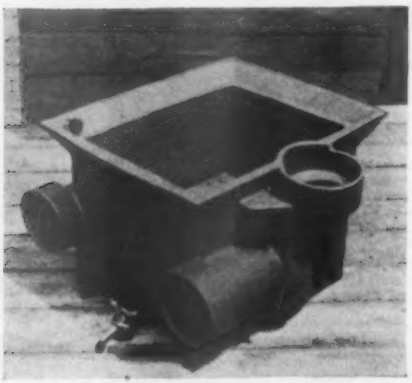
However, there are still other possibilities for the stoneware clays of Pennsylvania, Ohio, Indiana, Kentucky and Illinois which have not yet been realized up to the present time in the

FIG. 16.



View of stoneware condensing coils.

FIG. 17.



View of complicated stoneware apparatus.

production of kitchen specialties, cooking ware, containers for the drug trade, etc. It would be necessary, however, to produce ware of more attractive appearance than was possessed by the old crude stoneware. The same type of clay is also particularly

suited for the manufacture of glazed bricks, floor tiles, etc. It would seem thus that the old stoneware industry is capable of being revived in several directions.

Majolica pottery is being made in considerable quantities and in low-priced grades in the form of jardinieres, etc. A gradual improvement is being observed as regards the appearance of this kind of pottery and some of it may be considered as belonging to the type of semi-art ware.

The table ware produced in the United States consists essentially of two kinds of pottery, white ware and porcelain. The former possesses invariably a white, porous and opaque body while the latter is white, impervious to liquids, dense and more or less translucent. According to the degree of porosity there are several grades of white ware, that called "white granite" being the densest and whitest. Trade names such as "semi-porcelain," "Ironstone China," "Vitrified Hotel Ware," etc., are apt to be misleading since no pottery body should be termed porcelain or vitrified unless it really does not absorb water and shows the characteristic dense structure of porcelain. White ware bodies may absorb from four to ten per cent. of water. Both white ware and porcelain are produced from a mixture of kaolin, ball clay, feldspar and ground quartz (flint), the difference in composition being principally a smaller content of feldspar in the case of the white ware, and a larger proportion of this constituent in porcelain. Since feldspar is the fluxing and glass-forming component it is evident then that more of it is required to produce a vitreous body than a porous one. The temperature of firing of porcelain likewise is higher.

In the manufacture of white ware, of the composition: Kaolin 35 per cent., ball clay 15 per cent., feldspar 15 per cent. and flint 35 per cent., the first or biscuit firing carries the temperature to about 1290° C. while the glaze or glost burn does not as a rule exceed 1190° C. This practice follows that employed in the manufacture of the English earthenware with the difference that the latter has its glaze fused at a lower temperature than is common in American potteries, not exceeding as a rule 1120° C. The glaze of the English earthenware is hence considerably softer than that of the domestic ware, a fact not commonly realized by users.

American porcelain consists usually of about 46 per cent. of

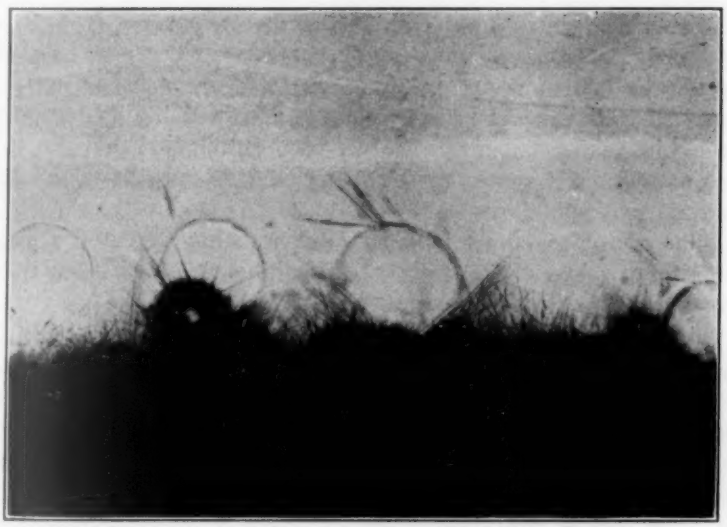
clay (kaolin and ball clay), 24 per cent. of feldspar and 30 per cent. of ground quartz. In its first firing it is carried to a higher temperature than white ware, usually to approximately 1330° C., in order that the fusing feldspar may cement together the quartz and clay to a vitreous, non-absorbent, and translucent mass. The glaze is fused on at practically the same temperature as in white ware. It is evident that the manufacture of American porcelain is derived from white ware practice which again has come to us from the English earthenware. On the other hand, the domestic porcelain differs quite radically both from the English bone china and the hard porcelain of the European continent. The glassy matrix of bone china is composed of a solution of feldspar and calcium phosphate (due to the use of calcined bone) and the material, although of beautiful texture is very much more fragile. Its glaze, like that of English earthenware is quite soft, due to the high content of lead oxide and boric acid. The European hard porcelain, on the other hand, reverses the English and American process inasmuch as the first burn (biscuit) is carried only to a very low temperature, about 990° C. The glaze is then applied and the ware finished at a temperature of approximately 1410° C. A glaze maturing at this temperature must in the nature of the case be free from lead oxide and boric acid and hence is certain to be very much harder than the white ware and the bone china glazes. The body and the glassy coating thus unite most intimately, a fact illustrated by Fig. 18. This photograph was taken at the junction of body and glaze and shows the needle-like crystals of sillimanite penetrating into the glass. A hard porcelain of this type would consist of about 55 per cent. of clay substance (kaolin plus ball clay), 26 per cent. feldspar, and 19 per cent. of ground quartz (flint). A glaze for this kind of body would consist of 167.4 parts (by weight) of feldspar, 55 whiting (calcium carbonate), 21.6 magnesium carbonate, 64.5 kaolin and 282.0 of ground quartz.

As far as toughness and sturdiness is concerned the American vitreous porcelain is very satisfactory. Its only defect is the greater softness of the glaze which is not so resistant to abrasive and solvent action as the European type. This could be overcome to a considerable extent by raising the biscuit firing temperature to about cone 11 or 12 (1350 to 1370° C.) and likewise increasing the glost temperature to cone 5–6, 1230 to 1250° C. This would

make possible the use of glazes free from lead oxide, though not from boric acid and the glazes thus produced should answer all requirements. Such a change would not necessitate any such far-reaching modifications of the manufacturing process as would be involved if the European hard porcelain process were adopted.

Hard fired porcelain proper is being manufactured in the United States to a limited extent by makers of chemical porcelain.

FIG. 18.



Micro-section, showing junction of body and glaze with sillimanite crystals growing into glaze. German porcelain.

There is no reason why the demand for this kind of product should not be entirely supplied at home. The technic is more difficult of course owing to the high-burning temperature and more precautions must be taken to prevent warping and deformation by the use of special supports and devices. Still there is no doubt but that potteries now producing hard chemical porcelain will soon begin the manufacture of table ware made from the same material. It must be supposed therefore that a considerable production of hard fire porcelain is to be expected in the United States within the near future.

Refractory (Marquardt) porcelain, hitherto made only by the Royal Porcelain Manufactory (Berlin), is also being produced

in this country, its manufacture having been introduced by the Pittsburgh laboratory of the Bureau of Standards.

Porcelain for electrical purposes and of excellent quality is being manufactured in the United States in large quantities. Its general composition corresponds to a mixture of 50 per cent. of kaolin and ball clay, 30 per cent. of feldspar and 20 per cent. of ground quartz. Electrical porcelain is fired to a temperature corresponding to pyrometric cone No. 10, or about 1330° C. Probably no kind of clay product is subjected to such severe service as high tension porcelain. It must hence be free from mechanical defects and must show perfect vitrification. Before leaving the factory the porcelain is subjected to exacting electrical tests. European electrical porcelain is fired to a higher temperature, cone 14–15, but it has not yet been established that the foreign material is superior to the American, though this claim has been made repeatedly.

The requirements of modern conditions have created a large and growing branch of the porcelain industry which specializes in the manufacture of sanitary ware of all kinds. The body used in this type of product is a true porcelain, showing practically no absorption. For larger pieces, such as bath-tubs a porous fire-clay body is employed more frequently, covered with a porcelain engobe and a glaze, finished in one fire.

The subject of pottery cannot be dismissed without referring to modern American achievements in art ware. The pioneer in this field has undoubtedly been the Rookwood pottery at Cincinnati, which has received world-wide recognition for its characteristic and beautiful underglaze decoration and the versatile development of a series of technics which have been imitated far and wide. Beautiful porcelain is being produced in Trenton (Lennox) and the decorative treatment of our commercial porcelain is undergoing steady improvement. A considerable number of large and small potteries and individual artists are steadily adding to the production of truly beautiful ceramic ware. Much is still to be accomplished and with increasing appreciation of the artistic handicrafts, there is every reason to believe that a still more vigorous development in ceramic art is to be expected.

The several American pottery industries manufacturing white products, whether these be porcelain or whiteware, are confronted by two important questions. One of these is the supply of domes-

tic kaolin of high grade, corresponding in quality to the well-known English china clay. This is probably one of the most serious problems with which we have to deal. At the present time, contrary to the statement of publicists, there is no American kaolin which is the equivalent of the best grade of the English. It is true that ware of excellent whiteness can be made of a mixture of the washed North Carolina kaolins and secondary kaolins like those from Georgia and Florida, but it is likewise true that the winning and preparation of the Appalachian kaolinitic raw materials represent by no means a stable mining industry and source of supply. If we could count upon securing a sufficiently large volume of North Carolina kaolin in its purest form, the whole situation would be different, and there would be no question as to the kaolin situation. Unfortunately, not only is the crude weathered rock, which is the source of the kaolin, extremely variable in its yield and the content of impurities like quartz, feldspar and especially of mica reach very high proportions, but the methods of washing, in part due to lack of centralization and lack of capital, are frequently of a very primitive character and lacking entirely in technical control. Other known deposits of primary kaolin as those of Delaware, Connecticut, Maryland, Virginia, Pennsylvania, Wisconsin, Colorado, California, etc., are not sufficiently extensive or are lacking in whiteness. Definite information is lacking regarding many occurrences. It is to be regretted that no comprehensive survey has as yet been made of the kaolin resources of the United States. If concerted action had been taken by the users of these clays, there is no doubt but that it would have located deposits of kaolin which by proper mixing could be made to serve every purpose.

The other important economic question relates to the more efficient utilization of fuel in the manufacture of pottery and allied products. If we stop to consider that never more than 5 per cent. of the heating value of the coal is utilized in actually bringing the ware to the required temperature in the type of periodic kiln in use to-day, it seems inevitable that in the very near future far-reaching advances must be made. The type of kiln most promising for this, as well as other clay industries, dealing with comparatively small units, is the tunnel kiln. There are available in this connection the Faugeron or the Didier-March kiln already discussed in connection with the burning of brick and

the Dressler kiln, an English invention. The latter is particularly promising for firing glazed products since it makes unnecessary the use of saggers, fire-clay boxes employed for the purpose of protecting the ware from ashes and impinging flames. Its construction is unusual and revolutionary, since the kiln charge is heated principally by convection through air currents heated by coming in contact with longitudinal heating or combustion chambers located on each side of the tunnel, as illustrated in the diagram of Fig. 19. Here the heated air, having been raised to a high temperature, by coming in contact with the surface of the combus-

FIG. 19.

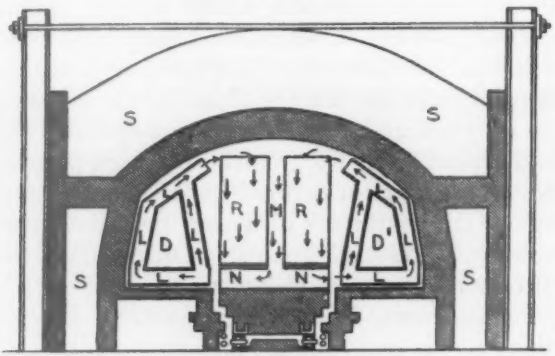


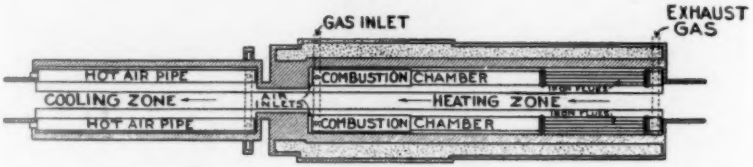
Diagram showing construction of Dressler kiln through the hot zone; D, combustion chambers R, ware to be fired; L, M, N, air passages.

tion chamber, rises to the height of the tunnel, and being cooled upon coming in contact with the ware it descends to be again heated and continues its cycle. Radiation also comes into play, but the use of double-walled pieces in the construction of the heating chamber, illustrated in the diagram, which provide rapid circulation over the hot surface, is quite effective in screening it from the ware, since the outside shell is not very much hotter than the ware itself.

The continuous kiln principle requires that the heat of the finished ware be utilized in preheating the air used in combustion, or in doing other useful work. In the Dressler kiln this is accomplished by reversing in the cooling zone the cycle maintained in the heating zone. Here the finished ware furnishes the heat, imparting it to pipes which conduct the air needed for combustion. The ground plan of this kiln is shown in the diagram of Fig. 20. This

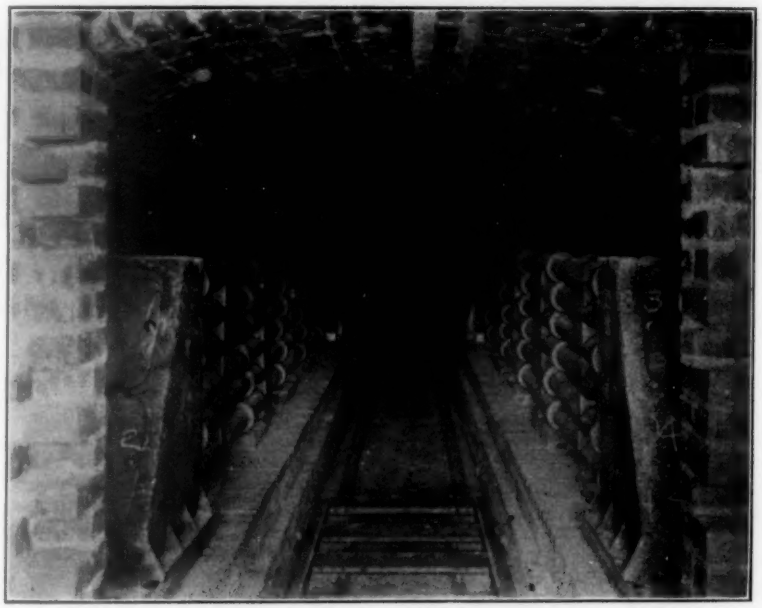
kiln is capable of firing clay products with a coal consumption of from 5 to 12 per cent. of the weight of the ware. It is admirably suited for firing glazed ware, and there is no doubt but that it will find extensive application not only in the ceramic but also in the

FIG. 20.



Plan of Dressler kiln.

FIG. 21.



View showing interior of Dressler tunnel kiln.

metallurgical and other industries. The kiln is capable of being controlled with ease. It requires gaseous fuel, in the form of producer or natural gas, though it may be adapted also to oil firing. The photograph of Fig. 21 shows the interior of the tunnel.

The temperature which can be reached in this kiln is limited only by the refractoriness of the material from which the heating

FIG. 22.

View showing use of Didier-March tunnel kiln for burning porcelain. Car entering kiln.

chamber is constructed. The ware entering the kiln is heated promptly by the use of iron heating pipes through which the cooled products of combustion are conducted.

The application of the Didier-March kiln to the firing of pottery is illustrated in the photograph of Fig. 22.

In addition to improving the firing process in the pottery industries, the mechanical side of the shaping process is now being developed in line with the modern ideas of efficiency, making it possible to save time in every manipulation. Thus, it has been proposed to construct revolving tables carrying a number of molds so that each operator performs only one manipulation. The molds thus come to the jiggerer already containing the proper amount of clay body, requiring on his part only the operation of the jiggering tool. The molds are then raised ready to be removed. The automatic operation of such tables makes it possible to increase the production decidedly and hence to lower the cost of production accordingly. Also plans are under way to dry pottery in a continuous operation by conveying the ware on pallets through a drying chamber using chain carriers.

Thus, the American clay industries may be said to be in a state of continuous growth, and there is every reason to believe that they will assume an increasingly greater importance in our national industrial activity.

Nickel Silver. ANON. (*The Metal Industry*, vol. 14, No. 12, December, 1916.)—The name "nickel silver" naturally creates the impression that this light colored metal is an alloy of nickel and silver, particularly when employed for articles of tableware manufactured by the silversmith. It contains however no silver, and even of nickel there is not more than 25 per cent., the remaining components being copper and a less amount of zinc. Ductile nickel silver suitable for table ware should be composed of 60 copper, 25 nickel, and 20 zinc or thereabout.

Nickel is the component which gives the alloy its silver-like color and resistance to corrosion. With an increasing amount of nickel the melting point rises and the tendency to produce gases in the crucible increases likewise. Finally the greater the percentage of nickel, the harder the alloy. Copper is the most ductile component, and a high content of this metal is desirable if the metal is to be subjected to rolling, stamping, drawing or spinning operations.

The value of the zinc lies in its effect of lowering the melting point and counteracting the gas-forming tendency of the nickel in the crucible. To what an extent the presence of nickel imparts its color to the alloy may be realized by an inspection of the United States five-cent piece. These coins contain 25 per cent. of nickel and 75 per cent. of copper, yet they show no trace of the deep color of their large copper content.

31,000 Horse-Power Turbines. ANON. (*Engineering News*, vol. 76, No. 20, November 16, 1916.)—The three turbines built for the initial installation of the Tallassee Power Company, a subsidiary of the Aluminum Company of America, at its Yadkin River development in North Carolina are by far the largest single-runner Francis turbines yet built. The remarkably steady load to be furnished by the nearby aluminum works permits of an efficient use of very large generating units, larger than is commonly desirable in general practice. Each turbine will develop 27,000 horse-power at maximum efficiency and 31,000 horse-power at full gate. Each turbine drives an 18,000 kilovolt-ampère, 36-cycle, 1320-volt three-phase generator with its exciter on top.

The notable points of interest are the use of steel-plate scroll casing embedded in concrete and a scheme of dismantling the runner from below without disturbing the generator or disturbing much of the turbine itself. The runner diameter is 108 inches; the speed 154 revolutions per minute; and the head, 165 to 180 feet. The casing inlet is 12 feet in diameter, and a tapering thimble connects to 15-foot penstocks. The upper part of the draft tube is of cast iron and telescopes into the section below, which is moulded in the concrete substructure. The draft tube is 11 feet in diameter at the top, but immediately begins to flare; and it flattens as it makes the usual right angle turn, the outlet being 32 feet wide and 13 feet 3 inches high.

Do the "Red Beds" of Wyoming Contain Potash Salts? ANON. (*U. S. Geological Survey Press Bulletin* No. 297, November, 1916.)—The Embar formation of Wyoming is known chiefly for its extensive phosphate beds, which are supposed to have been derived in some manner from animal remains. The rocks contain abundant fossils, many of which are phosphatic, and all of which prove that the Embar beds of western Wyoming were deposited in the sea. Recent study of the eastward extension of the Embar formation in Wyoming shows that along the east margin of this ancient sea, or throughout the Bighorn Mountain region, the climate was probably more arid than that of any part of Wyoming to-day. By long evaporation beds of gypsum were deposited at some places in arms of this sea to a thickness as great as 100 feet. It is a question of practical importance whether beds of salt, and perhaps of potash salt, may also have been deposited in this formation and whether they may now be found below the surface. The United States Geological Survey, Department of the Interior, urges that oil men, in drilling through the Chugwater and Embar red beds in Wyoming collect samples of drillings and of brines and submit them to the Survey for examination as to their possible potash content.

A paper by D. Dale Condit, describing the relations of the Embar and Chugwater formations in central Wyoming, and designated professional Paper 98-O, may be obtained on application to the Director of the U. S. Geological Survey.

THE ORGANIC NITROGEN COMPOUNDS OF SOILS AND FERTILIZERS.*

BY

ELBERT C. LATHROP, Ph.D.

INTRODUCTION.

THE present paper is a contribution to our knowledge of the chemistry of the nitrogenous portion of the soil organic matter. The investigations set forth were undertaken with a view to determine the chemistry of such nitrogenous soil compounds; to establish their distribution in agricultural soils; to define their origin and the biochemical changes which they undergo in the soil; and finally, to interpret the action and availability of the nitrogen of soils, peats and organic fertilizers.

Organic matter is that feature which distinguishes an agricultural soil from sand or powdered rock. Although it has been recognized for a number of centuries that the presence of organic matter in soil was a necessity for agriculture, it was not until the closing years of the eighteenth century that stress was laid upon the importance of this material in its relation to crop production. One of the most prominent writers of that day, the Earl of Dundonald, considered the organic matter of the soil to be the chief factor in crop production. While later investigators have shown that organic matter is by no means the only factor to be considered in soil fertility, they have demonstrated that it is of decided importance, not only from the chemical viewpoint but from the physical and biological as well. It has in fact become an axiom that any system of agriculture which tends permanently to decrease the organic matter of the soil is neither scientific nor profitable.

Although many investigations concerned with the chemical nature of the organic matter of soils have been made, it may be said that it is only within the last decade that this complex problem has begun to be solved. The lack of progress in this field of

* Contribution from the Laboratory of Soil Fertility Investigations, communicated by Dr. Oswald Schreiner and published by permission of the Secretary of Agriculture.

research has been due in no small measure to the fact that the biochemistry of the products of plants and animals, which eventually go to form the organic substances of soils by processes of decay, was itself so imperfectly understood. A contributing cause probably lay also in the fact that, while organic matter, or humus of soils, was known empirically to be of agricultural value, the investigations as to its more exact chemical nature were considered to be of greater theoretical than practical importance as compared to other soil studies, and therefore investigations concerning the nature of humus were often of a purely incidental nature.

The impelling necessity of learning more exactly the chemical and biochemical character of soil organic matter came with the observation that the infertility of certain soils could be explained only on the ground that they contained substances which were deleterious to plant growth. Experiments with aqueous extracts of these soils showed that these deleterious substances must be of an organic nature, and it was further demonstrated by Schreiner and Reed (1907)* that organic compounds likely to occur in soils were toxic in small amounts. Proceeding on this theory Schreiner and Shorey in 1908 succeeded in isolating from an infertile soil an organic hydroxy-acid, dihydroxystearic acid, which proved to be toxic in low concentrations to wheat seedlings grown in water culture solutions. At the same time they isolated three other compounds from soils: One was a nitrogen compound related to pyridine, picoline carboxylic acid by name, previously isolated from a Hawaiian soil by Shorey (1906), which proved to be only slightly toxic to wheat seedlings in water culture solutions; the other two were an acid and an alcohol, respectively, previously undescribed in the literature. These were without effect on plant growth.

The isolation from infertile soils of these two harmful organic substances furnished the material proof that certain soils may be infertile, not on account of the lack of any essential elements, such as potash, phosphorus, or nitrogen, but because of the presence of organic compounds in the soils, detrimental to the normal growth of crops. This idea, really a very old one, has met in the past with much favor and also with much criticism. It was advanced as a working hypothesis, because the idea seemed logical and right, but was discarded because no adequate proof of its validity could be furnished, due to the undeveloped state of science at the time.

* For reference see Bibliography under name and date.

With this new proof of an old theory many questions arose which concern both practical and theoretical agriculture in respect to soil fertility. The whole question of soil humus, the process of humification, was opened up anew. Could not beneficial compounds in soils as well as toxic and neutral compounds exist? Were there not ways in which the decay of the organic matter of the soil might be controlled and directed, so that instead of producing poisonous compounds in the soil, neutral or even beneficial compounds would arise?

It is obvious that many procedures which are the every-day practice of the farmer, such as drainage, irrigation, mulching, inoculation with bacteria, addition of fertilizers and stable manures, etc., all exert more or less influence on the course of the chemical changes taking place in the soil. It is also equally obvious that there can be no intelligent chemical control of any process unless the chemical nature of the materials involved is thoroughly understood. It therefore became essential to make a systematic chemical and biochemical study of the organic matter of soils. With no established facts and no methods of attack worked out, progress was necessarily slow at first, but gained speed with each compound isolated and identified, until now there have been isolated from soils about fifty definite organic compounds. An idea of the diverse chemical nature of these may be obtained from the fact that representatives of the following large classes of organic compounds have been isolated from soils: Acids of both the aromatic and aliphatic series, higher alcohols, aldehydes, hydrocarbons, carbohydrates, resins, esters, glycerides, glucosides, amino acids, nucleic acids, proteoses and peptones, amines, purine bases, pyrimidine bases, various other nitrogen and sulfur containing compounds, etc. These compounds may be considered to cover fairly well the principal classes of compounds encountered in other lines of biochemistry, and therefore the knowledge in regard to the chemical relationships, origin and processes of change accumulated in such other lines can be directly applied to the understanding of the biochemical changes in soils and the constitution of soil organic matter. Thus it has been possible to throw much light upon the biological and biochemical changes in soils so that the old views of soil organic matter, soil humus and the process of humification have been either radically modified or completely overthrown.

These compounds, isolated from soils, have been tested in regard to their effects on plant growth. In water culture solution experiments, and in several cases in pot and field tests as well, some of these compounds have been found to be toxic, others neutral, and quite a few beneficial to plant growth. To this latter class of compounds belong many of the nitrogenous compounds found in soils. Indeed, some of these nitrogenous compounds seem to be utilized by the plants with such ease that they equal in nutritive value the nitrates themselves. It is chiefly with such nitrogenous compounds that the present investigation is concerned.

THE SOURCE OF NITROGENOUS MATERIALS IN SOILS.

The quantity of total nitrogen in soils varies from a few hundredths of a percentage in light sandy soils to five-tenths of a percentage or more in rich, heavy loams. Peats and mucks, which from an agricultural viewpoint will be considered as soils high in organic matter in this paper, contain from five-tenths of a percentage of total nitrogen in the case of light mucks to about four per cent. in the case of some peats. Of the total nitrogen in soils, normally only about one-tenth of a percentage exists in the form of ammonia or ammonium salts and about one to two per cent. in the form of nitrates. The remaining portion of the total nitrogen, ninety-seven to ninety-nine per cent., exists in organic combination.

In view of the fact that the ultimate source of the organic constituents found in soils is the débris of plants or animals and that organic nitrogenous compounds are a constituent part of all protoplasm, a comprehensive conception of the more immediate sources of the nitrogenous matter of soils may best be obtained by a consideration of the sources of soil organic matter in general. The organic matter of soils may be divided into two general classes: living and non-living. To the former class belong earthworms, beetles, larvæ, molds, yeasts, bacteria, protozoa, higher fungi, algæ, roots and rootlets of the higher plants. The greater portion of the organic matter consists, however, of non-living matter.

This organic matter may be conveniently subdivided into four classes:

(1) The materials furnished by the recent generations of

living matter in the soil, or by recent additions of organic manures, fertilizers, or plant débris, and other extraneous matter, which has not yet been in the soil for a long enough time to decompose and still retains to a very great extent the physical structure of its former self. However, chemical changes incident to the death of the plant and animal cells have already occurred in this material, such, for example, as those brought about by the interaction of soluble compounds, non-reactive in the living cell, or by autolysis due to the enzymotic action within the dead cell. These processes may produce both lysis and synthesis and are probably of considerable importance in the transformation of organized material into humus.

(2) Material which has either partially or wholly lost all vestige of its original structure. Such substances have already undergone considerable chemical change either by direct oxidation or reduction, or by chemical changes produced either by the organisms of the soil, or by other agencies. To this class of organic soil material belong all compounds intermediate between the complex organic substances which composed the original plant or animal materials entering the soil and the final products of their decay. This class makes up the major portion of the organic matter of ordinary agricultural soils.

(3) Substances which decompose only very slowly in the soil or not at all. In this connection it is interesting to note that Schreiner and Brown (1912), in investigating this resistant class of organic material, discovered in many soils particles of coal. lignite, charcoal, remains of insects, resins, etc. There is also some evidence that to this class of more or less organized substances there should be added certain very complex chemical compounds such as those obtained synthetically by Maillard (1913) through the interaction of certain carbohydrates and amino acids, compounds which seem to be resistant to chemical treatment.

(4) The synthetic products of the life processes of the microorganisms in the soil, both those that fix atmospheric nitrogen and those that synthesize into more complex compounds, such as proteins and nucleoproteins, the nitrogen which is present in the soil in the simpler forms of ammonia, nitrates, amides or amino compounds.

CONDITIONS CONTRIBUTING TO THE CHANGES IN SOIL ORGANIC MATTER.

The organic matter of soils must be considered to be material in a dynamic state. It is not only the product of change, but at the same time it is continually in a state of change. Two processes are continually going on in soils, one which is essentially lysis, the breaking down of the complex compounds into the simpler by the processes of hydrolysis, oxidation, reduction, etc., and the other synthesis, or the building up of complex compounds from the simpler ones.

The factors which are operative in these changes constantly taking place in the soil are many and varied. Possibly the most important are the microörganisms of the soil, which find the organic matter a favorable medium for growth. No fact, however, concerning microörganisms is probably better established than that they are profoundly influenced by the nature of the medium, not only in their habits of growth but also in the products which they produce. Such factors as moisture, aeration, acidity or alkalinity, the nature of the organic matter, the mineral constituents of the soil, the addition of fertilizers, etc., will, therefore, exert a marked influence, not only on the types of the active microörganisms, but also on the nature of the changes which they produce in the soil.

At the same time these various factors influence also the purely chemical changes taking place in the soil. That is, the course of the decomposition will be different according to the factors concerned in the decay. When certain conditions predominate, the compounds produced in the soil will be normal and beneficial. If, however, another set of conditions prevails, the compounds may be abnormal and harmful. In soils there is a balance of the beneficial and harmful factors, soil fertility or infertility being the resultant of the two groups. As one or the other of the groups gains ascendency, the fertility is raised or lowered, as the case may be.

PREVIOUS INVESTIGATIONS.

Among the first investigators to study the organic matter of soils may be mentioned Einhof (1805), Braconnot (1819), Mitscherlich, Sprengel (1826), Boullay (1830), Klaproth (1833), Malguti (1835), Thompson (1840) and Mulder (1840–1862). Of these investigators Mulder is the most quoted and

his work and ideas in regard to the chemical nature of the organic matter of soil had in a large measure held sway until the close of the last century.

The investigations of these early workers naturally appear somewhat crude in the light of today. The organic chemistry known to them was essentially a determination of elementary composition and most methods utilized at the present time for the isolation of organic compounds were unknown, as were most of the compounds involved. The organic compounds of the soils they considered to be acids of high carbon, hydrogen, and oxygen content, and these but few in number.

Nitrogen was considered to be present in the humus of soils as an ammonium salt of the "humic acids." In this regard Mulder states:

"In a good arable soil—that is, one in which the organic constituents are as far as possible decomposed—none of these substances (the humic acids) contain nitrogen as a constituent element; all of their nitrogen exists in the state of ammonia." Mulder, however, seemed to believe that the plant albumins were the original source of the nitrogen of soil.

Detmer (1871) did not come to this conclusion at first, although later he seems to have taken Mulder's view. He claimed that the nitrogen in the soil was in organic combinations, basing his conclusions on the facts that the humic acid, when treated with potassium hydroxide, gave off no ammonia and that about 21 per cent. of the total nitrogen was liberated on treatment with alkaline hypobromate. This is the first indication of the existence of organic nitrogen compounds in soils.

Simon (1875) claimed that peat absorbed nitrogen from the air with the formation of ammonium compounds, a claim which was later disproved.

Ritthausen (1880) thought that the high nitrogen content of peat was due to the absorption of ammonia with the formation of complex, difficultly decomposable compounds.

v. Sivers (1880) found that only a small amount of the nitrogen of peat could be driven off as ammonia on heating with potassium hydroxide and, although he offered no material evidence, he considered the nitrogen of peat to be present largely in protein form.

Grouven (1883) found in various samples of peat that only

one-fifth of the nitrogen was driven off when heated with milk of lime for several hours, and only one-twentieth when heated with potassium hydroxide for two hours.

Loges (1886) found that a hydrochloric acid extract of a soil gave a precipitate with phosphotungstic acid, which is generally recognized as a precipitant for basic nitrogenous compounds.

Up to this time, aside from Detmer's experiments, the significance of which was apparently overlooked, nothing definite had been determined in respect to the form in which nitrogen existed in soils and peats excepting that a small amount was present as ammonia.

In 1886 Berthelot and André concluded that the nitrogen in the soils they studied was not present as ammonia, but in organic form, partly as amides.

A. Baumann in the following year suggested the presence of amide compounds in the soil, since he obtained, on boiling the soils with hydrochloric acid, ammonia, which was not originally present in the soil.

Eggertz (1889) found that the nitrogen content of thirteen samples of humus varied from 2.5 to 6.4 per cent. and states that the nitrogen was present in organic form and not as ammonia.

Warington (1887) at Rothamsted demonstrated the presence of small amounts of soluble amides in soils which had been heavily manured.

Sestini (1899) contradicted the idea that any great amount of amides could be present in soils and reports that a portion of the nitrogen was present in the form of amino acids.

Dojarenko (1901–1902) obtained large amounts of amino nitrogen from the black soils of Russia. He was the first to make a quantitative study, applying the method of Sachsse and Kormann as modified by Boehmer (1883). He found that from 21 to 71 per cent. of the total nitrogen of the "humic acid" was present in the form of amino compounds, from 5 to 20 per cent. in amido form and as much as 2 per cent. in the form of ammonia.

Shorey (1905) with a view to classifying the nitrogenous compounds, applied the method of Hausmann (1899) modified by Osborne and Harris (1903) to the study of Hawaiian soils. He obtained in the acid solution 78 per cent. of the total nitrogen

in the soil, more than half of which existed as "humin" nitrogen, and the remainder as ammonia, diamino acids, and monoamino acids.

None of the investigators so far considered dealt with the isolation and identification of any definite organic nitrogenous compounds from soils. They merely attempted to classify the nitrogenous portion of the organic matter. The net results indicate that the soil contains either amides or amino acids or else compounds, which on heating with strong alkalies or acids, decompose, giving reactions for amides or amino acids. Such evidence would suggest that the nitrogen of the soil arises largely from protein materials and probably contains proteins.

It remained for Shorey in 1906 to isolate the first definite organic compound from soils. Considering the preceding investigations, it is rather surprising that the compound was not a primary decomposition product of proteins, but was a pyridine derivative, picoline carboxylic acid. Berthelot and André had in 1891, however, obtained results on the distillation of soils which suggested to them the presence of a pyridine compound. The presence of this compound in the Takoma soil was later reported by Schreiner and Shorey (1909), who suggest that this acid, which is slightly toxic to wheat seedlings, probably arises from the secondary decomposition of proteins in the soil.

The investigations dating from 1906 may be divided into two classes (1), those dealing with analytical methods with the view to classifying the forms in which the soil nitrogen occurs, and (2), those dealing with the actual isolation and identification of organic nitrogenous compounds from soils.

To the first class belong the extended investigations of Jodidi (1909, 1911) on peats of Michigan and soils of Iowa. He hydrolysed the peats with strong mineral acids and determined the forms of nitrogen by approximately the same method as that used by Shorey. He found that on hydrolysis about two-thirds to three-fourths of the nitrogen was in the form of monoamino acids, one-fourth in the form of amides and the rest in the form of diamino acids. With the Iowa soils he went still further and with the method of Sörenson (1907) found that practically all of the nitrogen classed as diamino acid nitrogen existed in amino form, while from 40 to 92 per cent. of the monoamino acid nitrogen existed in amino acid forms. The amide nitrogen was found

to be composed entirely of amides, since only ammonia was obtained when the acid extract was distilled with magnesia.

Lathrop and Brown (1911), by use of the Hausmann method as modified by Osborne and Harris, made a study of a soil located at the Pennsylvania State College Agricultural Experiment Station, which had been subjected to different manurial treatments in respect to nitrogen, and found that the forms of nitrogen in the different plats varied.

Working with the soils of Hawaii, Kelly and Thompson (1914) found that the amount of nitrogen dissolved by boiling with strong hydrochloric acid was from 67 to 92 per cent. of the total nitrogen, and that the relative percentages of amide and basic nitrogen split off during hydrolysis stand in the reverse order to that in which they occur in vegetable proteins.

Potter and Snyder (1915) report studies on Iowa soils both by the use of the Van Slyke method (1911) on the hydrolysis mixture from the soils and by the use of the Kober method (1913) on a 1 per cent. alkaline extract of the soils. They conclude that the amount of amino acid and peptide nitrogen existing free in the soil is very small when compared with the amount of amino acids found after hydrolysis of the soils with acids, and that the amount of amino nitrogen was less than the ammonia nitrogen.

Chardet (1914) reports experiments on soils in which he extracted the soils with 2 per cent. sodium hydroxide solution and, after suitable procedure, determined the amino nitrogen according to the method of Sörenson. He states that the amino acids represent from 49 to 68 per cent. of the total nitrogen.

Schmuk (1914), working with Russian soils according to the modified method of Hausmann, concludes that the nitrogen in the soil is of a protein nature.

Suzuki (1907) reports results obtained by hydrolysing humus, from three different sources, with strong hydrochloric acid. The acid solution was subjected to esterification and fractional distillation according to the method of Fischer (1901, i, ii) for the isolation and estimation of the amino acids. He obtained by this procedure, alanine, leucine, aminovaleric acid, proline, aspartic acid, glutamic acid, traces of histidine and tyrosine, together with some unidentified acids. Suzuki concludes that humus is made up largely of proteins. His conclusion seems, however, from his experiments not wholly to be warranted, since some of the amino

acids which he found may have existed in that form in the humus and not have been differentiated by the method which he used.

Robinson (1911) succeeded in isolating both leucine and isoleucine from the acid solution resulting on the hydrolysis of Michigan peats with hydrochloric acid. He was also the first to subject peat to analysis by the Van Slyke method.

The investigations concerned with the isolation of definite organic nitrogenous compounds from soils have chiefly been conducted by Oswald Schreiner and his colleagues, Shorey, Lathrop, Walters, and Wise. These investigators have up to the present reported the following nitrogenous compounds in agricultural soils: The purine bases, xanthine, hypoxanthine, adenine and guanine; the pyrimidine base, cytosine; the hexone bases, histidine, arginine, and lysine; the pyridine derivative, picoline carboxylic acid; and the compounds, creatinine, choline, trimethylamine, tetracarbonimid, cyanuric acid, nucleic acids, proteoses and peptones. Fosse (1916) has recently added urea to this list of nitrogenous soil compounds, reporting it to have been found in forest, truck, humus, and virgin soils, in France.

The evidence obtained by all of these investigations leads to the conclusion that the larger portion of the nitrogenous organic matter normally present in soils consists of the primary or secondary decomposition products of protein and of protein itself. In this connection it is interesting to note that the organic nitrogenous fertilizing materials commonly added to soils also contain proteins or protein-like substances. From the strictly biochemical point of view, therefore, the changes taking place in the organic nitrogenous materials in the soil or in those added to the soil in the form of fertilizers, crop remains, etc., may be considered to be those of protein degradation.

THE PROTEIN MOLECULE.

The proteins are compounds of extremely high molecular weight, are generally in colloidal condition, and act as amphoteric electrolytes; facts of the greatest significance to biology. About 50 natural proteins are known and these are classified according to their origin and physical properties into a number of groups: Protamines, Histones, Albumins, Globulins, Glutelins, Gliadins, Phosphoproteins, Scleroproteins, and Conjugated proteins. In

addition, a large number of protein-like compounds, called polypeptides, have been synthesized.

Investigations on the chemical structure of the proteins were begun at about the same time as the investigations on the nature of the organic nitrogenous matter of soils and the unravelling of the latter problem has progressed with the solution of the former. The synthetic researches of Emil Fischer (1899–1906) and his co-workers on the structure of the protein molecule prove the accuracy of Hofmeister's view (1902) that the protein molecule is built up of amino acids combined principally in the form of acid amides according to the following structure:

$$NH_2.CHR.CO–(NH.CHR.CO)_x–NH.CHR.COOH.$$

Fischer has termed the combinations of the amino acids which he prepared, polypeptides, and by the method of preparation the arrangements of the amino acids in them is known. The chemical nature of an albumin is partly determined by the quantitative relationships of the different amino acids and partly by the arrangements of these in the molecule.

Several points regarding the constitution of the protein molecule have been fairly conclusively established which have a direct bearing on the study of soil organic nitrogen. On acid hydrolysis a small portion of the total nitrogen of the protein is liberated as ammonia from the acid amide group ($CO–NH_2$) in the protein molecule. From a study of the amounts of ammonia formed by the hydrolysis of a large number of proteins by acids and the amounts of ammonia formed by heating these proteins with a solution of sodium hydroxide, Osborne, Leavenworth and Brautlecht (1908, ii) conclude that it is highly probable that the ammonia produced on acid hydrolysis results from an amide union ($–CO–NH_2$) in the protein molecule, and that the ammonia formed by treatment with alkali results from the disrupting of this union and from the destruction of arginine. By treatment with sodium hydroxide solution arginine is split into urea and ornithine and the urea is decomposed with the formation of ammonia. (E. Schultz, 1891, 1897, 1898.)

The greater portion of the nitrogen of proteins exists after hydrolysis in the form of NH_2 groups in amino acids. In the protein molecule, however, the greater part of the nitrogen is

present, not in the form of the amino group (NH_2) but in anhydride linkages, in imino groups (NH), as is shown by the limited reaction of the proteins with nitrous acid. However, Van Slyke and Birchard (1913), from a study of the action of certain proteins towards nitrous acid, conclude that one of the two amino groups of lysine, the ω-group, exists free in the protein molecule. Almost the entire amount of free amino nitrogen determinable by the nitrous acid method in the native proteins is represented by this ω-group of lysine. The α-amino groups which constitute the remaining and greater part of the nitrogen found after hydrolysis, are, in the intact molecule, practically all condensed into peptide linkages. With primary albumoses, the first decomposition products of protein, the relations are different; the free amino nitrogen in hetero- and proto-albumoses exceeds half of the lysine nitrogen by 3.0 and 4.8 per cent. of the total nitrogen respectively, indicating that an appreciable portion of the α-amino groups of other amino acids is uncovered even in these complex primary digestion products.

PROTEIN HYDROLYSIS.

Hydrolysis of the protein molecule by means of acids, alkalies, moist heat or enzymotic processes results in the introduction of water into the molecule at various definite places, with the concurrent formation of albumoses, peptones, polypeptides, amino acids and ammonia, the amounts and nature of the products depending on the specific protein and the reagents used. Some proteins are easily hydrolysed, while others break down only under energetic and prolonged treatments. The ease with which proteins are hydrolysed is a matter of much practical significance to soil fertility, since it is intimately connected with the question of the availability of nitrogenous fertilizers, a subject which will be more fully discussed in another portion of this paper.

The extent of hydrolysis of proteins with acids or alkalies depends not only upon the strength of the reagent but also upon the length of treatment. For example, by means of hot dilute acid, or the action of more concentrated acid in the cold, complex polypeptides have been obtained as partial hydrolysis products. The action of moist heat is less energetic than that of chemical reagents, generally inducing changes of a milder order. The final products of hydrolysis are ammonia and the amino acids.

Hydrolysis by the proteoclastic enzymes is, however, never

complete. With pepsin amino acids are said to be formed, only in small amount, the splitting of the protein resulting chiefly in the formation of albumoses, peptones, peptides and ammonia. It would seem, therefore, that pepsin is able to open up the anhydride ring of the protein at one or more junctures, but is not able easily to produce in this way free amino acids. The action of trypsin differs from that of pepsin, in that, although it cannot break down all proteins, requiring in many instances the action of pepsin first, it splits the protein more deeply, giving almost complete hydrolysis, with the formation of amino acids together with many of the products of peptic digestion. Trypsin and erepsin seem to be able to hydrolyse chains of amino acids with terminal carboxyl or amino groups, separating the imino group (NH) from the neighboring carboxyl, according to the general formula:

$$\underset{(1)}{CO-NH-}\underset{(2)}{C} \quad \text{becomes} \quad \underset{(1)}{COOH}, \quad \underset{(2)}{NH_2-C}$$

Another type of splitting occurs in the action of arginase, which splits arginine into ornithine and urea:[1]

$$NH_2 . CNH . NH . C_3H_6 . CHNH_2 . COOH - H_2O = NH_2 . CO_2 . NH_2 + NH_2 . C_3H_6CHNH_2 . COOH.$$

That even after prolonged action of trypsin on albumin, protein-like substances remain, and that all of the nitrogen present in the acid amide groups ($-CO-NH_2$) is not split off, have been shown by Fischer and Abderhalden (1903). After hydrolysis of an albumin with trypsin for several months these investigators obtained a polypeptide which on further hydrolysis with acids yielded glycocoll, alanine, leucine, proline, phenylalanine, aspartic acid, and glutamic acid. Since the polypeptide yielded the mono-aminocarboxylic acids on hydrolysis, it follows that the hydrolytic formation of ammonia is not complete by such enzyme action.

SPLITTING OF PROTEINS BY MICROÖRGANISMS.

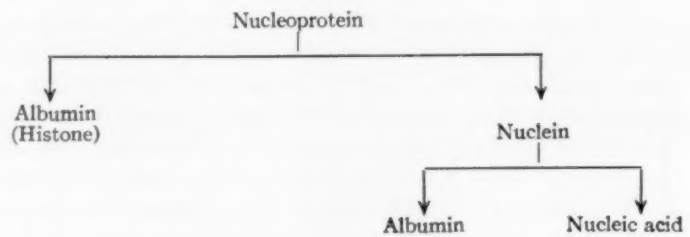
Numerous investigations concerning the action of microörganisms in the decomposition of protein materials have been carried on and the following general conclusions may be drawn

[1] See Kossel (1898); Kossel and Matthews (1898) and Kossel and Dakin (1904).

from them. There is little reason to suppose that the action of microörganisms is other than that of the enzymes which they produce. Kruse (1910) states that the bacterial proteoclastic enzymes resemble pepsin, trypsin, and erepsin in the mode of their action, but are somewhat different from these. Dox (1910) finds that the proteoclastic enzymes of mold are the same in action as those occurring in plants and animals. In addition to the purely hydrolytic enzymes concerned with the splitting of the complex proteins into amino acids, etc., other specific enzymes seem to be present either as extra- or intracellular enzymes of the microorganisms found in the soil. The degradation of proteins by microörganisms, then, proceeds along the same general lines as that produced by the proteoclastic enzymes or acids, but does not stop with hydrolytic cleavage, a deeper change taking place, with the formation of secondary protein decomposition products, such as ammonia and carbon dioxide in large quantities, together with amines, fatty acids, alcohols, aldehydes, methane, phenol, skatole, indole, hydrogen sulfide, etc.

NUCLEOPROTEIN DEGRADATION.

Perhaps the most complex of the compounds which enter the soil are the nucleoproteins. They are the common constituents of all plants, animals, bacteria, molds, etc., and occur, therefore, wherever these live and die. It may be well to follow the compounds which are formed by the chemical changes incident to the decomposition of this class of protein material. Lilienfeld (1892) has expressed the decomposition of a nucleoprotein by the following schematic representation:



The products of decomposition then are albumin, or protein, and nucleic acid. Protein materials have been isolated from the soil by Walters (1915) of this laboratory.

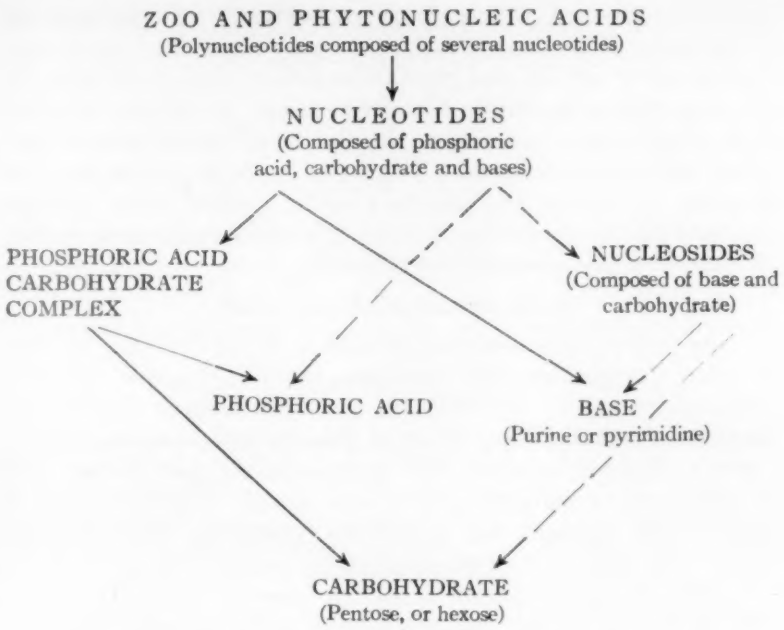
NUCLEIC ACID DEGRADATION.

Nucleic acid is a class name covering a large number of compounds, composed of carbon, hydrogen, oxygen, nitrogen, and phosphorus, occurring in plant and animal cells. Nucleic acids were isolated from soils by Shorey (1912, ii). They are very complex and yield on decomposition a number of compounds of less complex structure.

The proportion of the five elements in nucleic acids differs, depending upon the source of the acids, and this is due to the fact that the unit substances composing them are different. Thus, for instance, the nucleic acid from yeast, according to Herlant (1900), has the composition $C_{36}H_{48}O_{30}N_{14}P_4$; that from salmon, according to Schmiedeberg (1899), the composition $C_{40}H_{52}O_{25}N_{14}P_4$; and that from wheat, according to Osborne and Harris (1902), the composition $C_{41}H_{61}O_{31}N_{16}P_4$. Many hold the view that there are but two nucleic acids in nature, one the nucleic acid of the plant and the other the nucleic acid of the animal cells.

The constitution of these complex nucleic acids is not fully known, but the constitution of most of the dissociation products is known. As above mentioned, the dissociation products vary with the source of the acid. The hydrolytic products of the nucleic acid of plant origin are: Phosphoric acid, guanine, adenine, cytosine, uracil and pentose. The hydrolytic products of nucleic acid of animal origin are: Phosphoric acid, guanine, adenine, cytosine, thymine and lævulinic acid. The lævulinic acid is formed from a hexose group in the molecule of the nucleic acid.

While the simple end-products of the nucleic acids are those mentioned, the dissolution of the nucleic acid molecule does not take place in one step. There are several intermediary products or combinations of the above mentioned final products which have definite chemical and physical identity. The researches of Levene and of Jones have served to clear up to a large extent the nature of these intermediary products. The steps in the disintegration of the plant and animal nucleic acids can perhaps best be made clear by the following schematic representations:



The complex zoo or phytonucleic acids, for instance, those from wheat, yeast, salmon, are composed of simpler nucleic acids, which Levene has called nucleotides. The nucleotides are composed of phosphoric acid, carbohydrates, and bases, either purine or pyrimidine. Several of these nucleotides have been isolated, for example, guanilic acid (Levene and Jacobs, 1910), inosinic acid (Levene and Jacobs, 1911), cytidin-phosphoric acid (Levene, 1911), uridin-phosphoric acid (Levene, 1911), thymohexose-phosphoric acid (Levene, 1910). On further decomposition the nucleotide can part with its phosphoric acid on the one hand and yield a complex consisting of the base and the carbohydrate, designated as a nucleoside in the diagram, and on the other hand it can part with the base and leave a complex consisting of phosphoric acid and carbohydrate. Of the nucleosides a considerable number are known, guanosin, inosin, adenosin (Levene, 1910), and xanthosin (Levene, 1911), which are respectively guanine, hypoxanthine, adenine and xanthine combined with the carbohydrate. Further, from the nucleotides cytidin- and uridin-phosphoric acids, the nucleosides cytidin and uridin (Levene,

1911) are obtained, which consist, respectively, of combinations of cytosine and uracil with carbohydrates. Several of these compounds form well-defined crystalline bodies and form salts of the same type as the base contained in them. A definite carbohydrate-phosphoric acid complex has also been isolated and a crystalline barium salt obtained. This is the d-ribose phosphoric acid obtained by Levene and Jacobs (1908). All of these various products can then be broken down into phosphoric acid, carbohydrate, and base, purine or pyrimidine.

TRANSFORMATION OF THE BASES.

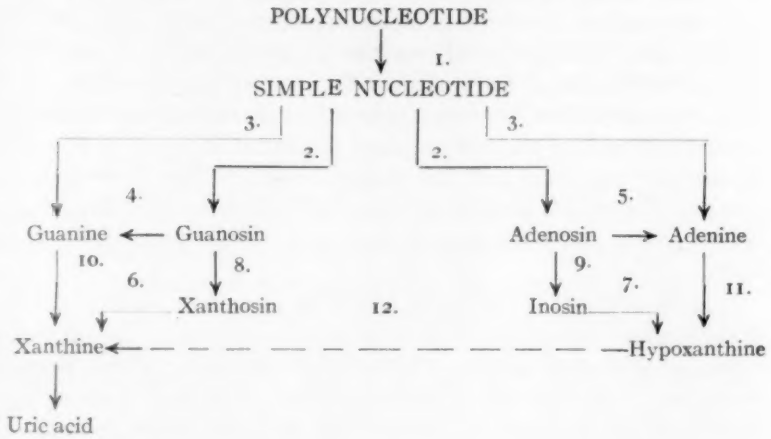
The purine and also the pyrimidine derivatives are capable of being changed one into the other, by both chemical and biochemical agencies. Nitrous acid has been used to effect such changes. Fischer (1882) changed guanine into xanthine, Kossel (1886) changed adenine into hypoxanthine, and Kossel and Steudel (1903) changed cytosine into uracil. Similarly Levene (1911) has changed the complexes guanosin, adenosin, and cytidin into xanthosin, inosin and uridin, respectively.

These changes produced by strictly chemical means are paralleled by the biochemical changes induced by bacteria and enzymes. It was shown by Schittenhelm and Schröter (1904) that putrefactive bacteria, especially coli bacillus, were able to convert adenine and guanine into hypoxanthine and xanthine. They also show that the bacteria have the power of splitting down the nucleic acid itself. This change of nucleic acids is brought about also by certain enzymes which have been called nucleases, such as erepsin. (Nakayama, 1904; Iwanoff, 1903; Sachs, 1905.)

Schittenhelm (1909) has shown that there is present in the pressed juice of lupine seeds an amidase capable of converting guanine into xanthine. Burian (1905) showed that enzymes were capable of oxidizing xanthine and hypoxanthine into uric acid. The existence of amidases capable of causing the conversion of the amido purines (guanine and adenine) into the oxypurines (xanthine and hypoxanthine) has been repeatedly demonstrated.

According to Levene and Medigrecaenu (1911, i, ii, iii) nucleic acids are not decomposed by any one ferment. Levene and LaForge (1912) have shown that in some nucleic acids the pyrimidine complex is very resistant to the hydrolytic action of dilute acids and of enzymes.

The changes induced by these various enzymes may perhaps best be shown by the diagram given by Amberg and Jones (1911):



ENZYMES WHICH PRODUCE THE VARIOUS CHANGES.

1. Nuclease
2. Phosphonuclease } Nucleotidases.
3. Purinenuclease }
4. Guanosinhydrolase }
5. Adenosinhydrolase }
6. Xanthosinhydrolase } Nucleosidases.
7. Inosinhydrolase }
8. Guanosindesamidase
9. Adenosindesamidase
10. Guanase } Purindesamidases.
11. Adenase }
12. Xanthinoxydase

The above exposition of the changes involved in the degradation of the nucleoproteins makes clear the fact that this operation takes place in many stages, and also that many of the intermediary, as well as the final products, are capable of being transformed the one into the other. This degradation can be brought about in many ways: By chemical means, such as the action of acids, alkalies, and steam under pressure; by microörganisms; and also by the enzymes of plants and animals.

THE PRODUCTION OF AMMONIA IN SOILS DUE CHIEFLY TO THE SECONDARY DECOMPOSITION OF PROTEINS.

Under natural conditions the changing of organic nitrogen into ammonia is the work of microörganisms in the soil. Müntz and Coudon (1893), studying the ammonification in sterilized and unsterilized soil showed that during two and one-half years there was no ammonia formation in the sterilized soil while the unsterilized soil in sixty-seven days produced from 41 to 100 milligrams of ammonia per 100 grams of soil. The investigations concerned with the process of ammonification cover a large number of years and a résumé of this work is not deemed essential here.

As has already been shown, when the protein material is hydrolysed a small amount of ammonia is formed due to the breaking down of the acid amide ($-CO-NH_2$) linkages of the protein molecule. The amount of ammonia thus produced is about 4 to 9 per cent. of the total nitrogen of the proteins. Repeated experiments have shown that the amount of ammonia produced during the decomposition of protein matter in the soil far exceeds these small amounts. For example in the experiment on the decomposition of dried blood, described in another portion of this paper, if ammonia were formed only from the splitting off of the amide group from the proteins of the dried blood the total amount of the ammonia formed during the course of the decomposition would be about 7 per cent. However, about 75 per cent. of the total nitrogen of the proteins was changed to ammonia during this decomposition. It is evident, therefore, that ammonia must be formed from other fractions of the protein molecule besides that containing the amide linkage. Experiments have shown that the greater part of the ammonia produced during the decay of protein material in the soil arises through what is known as the process of secondary decomposition.

In regard to the action of microörganisms on amino acids or the simpler polypeptides, it may be stated that the chemical changes involved depend largely upon the character of the organism, the conditions of growth, especially with regard to the presence or absence of oxygen, and the available source of nutrient other than amino acids.

While it is impossible to draw a distinct line of demarcation between the action of the putrefactive bacteria and of the aerobic bacteria and molds in the decomposition of amino acids, still, certain processes seem to belong to each.

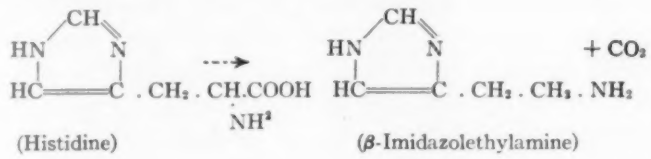
There are two general processes of decomposition of amino acids by the putrefactive bacteria. The first is the formation of amines according to the following general formulas:

(1) $R . CHNH_2 . COOH \longrightarrow R . CH_2 . NH_2 + CO_2$

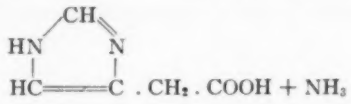
(2) $R . CHNH_2 . COOH + H_2 \longrightarrow R . CH_3 . NH_2 + H . COOH$

Most of the amino acids seem to yield amines on putrefaction, the formation of these following partly the first and partly the second reaction. Amine formation is prevented in the case of the monoaminodicarboxylic acids, since in this case the β- or γ-amino acid is formed: γ-aminobutyric acid from glutamic acid (Ackermann, 1910). The diamino acids especially favor this reaction, since, as Ellinger (1898–1900, i, ii) has shown, lysine and arginine yield Brieger's diamine bases, cadaverine and putrescine, respectively.

Ackermann (1910) has further shown that histidine is changed by the action of bacteria into β-imidazolethylamine according to the schematic representation:



The same investigator finds that under the same conditions some β-imidazolpropionic acid is formed from the histidine.



On the other hand it has been observed by Ehrlich and Pistschimuka (1912) that wild yeasts are able to freely change amines into alcohols with the formation of ammonia. Reaction (3):

(3) $R . CH_2 . NH_2 + H_2O \longrightarrow R . CH_2 OH + NH_3$

The second general putrefactive process consists in the formation of fatty acids by the splitting off of ammonia and the concurrent entrance of hydrogen, a process of reductive desaminization:

$$(4)\quad R \cdot CH\,NH_2 \cdot COOH + H_2 \longrightarrow R \cdot CH_2 \cdot COOH + NH_3$$

This process is illustrated by the formation of succinic acid from aspartic acid (Hoppe-Seyler, 1877); Neuberg and Capezzuoli (1909), and of oxyphenylacetic acid from tyrosine (Baumann, 1879–1880).

Almost all of the amino acids, if not all, are capable of change by this process. Sometimes two different sorts of decomposition take place simultaneously, with the resulting formation of a hydrocarbon. In this way Kerry (1889) attempted the explanation of the formation of methane from glycocoll.

$$CH_2\,NH_2 \cdot COOH + H_2 \longrightarrow CH_4 + NH_3 + CO_2$$
(glycocoll)

Aerobic bacteria more frequently oxidize the α-amino acids to fatty acids containing one less carbon atom, carbon dioxide and ammonia being set free:

$$(5)\quad R \cdot CH_2 \cdot CH\,NH_2 \cdot COOH + O_2 \longrightarrow R \cdot CH_2 \cdot COOH + NH_3 + CO_2$$

In this way is formed phenylacetic acid from phenylalanine (Baumann, 1883) and isovalerianic acid from leucine (Bopp, 1846).

Ehrlich has discovered that yeasts convert amino acids into alcohols, carbon dioxide and ammonia being formed; the net result of this reaction indicates neither oxidation nor reduction but simple hydrolysis:

$$(6)\quad R \cdot CH_2 \cdot CH\,NH_2 \cdot COOH + H_2O \longrightarrow R \cdot CH_2 \cdot CH_2OH + NH_3 + CO_2$$

This reaction proceeds in several stages, according to Ehrlich as follows:

$$\begin{array}{llllll} R & R & R & R & & \\ | & | & | & | & & \\ CH\,NH_2 & CH\,OH & CHO & CH_2\,OH & & \\ | & | & | & | & & \\ COOH & COOH & H \cdot COOH & CO_2 & & \end{array}$$

Amino acid ⟶ Hydroxy-fatty acid ⟶ { Aldehyde, formic acid } ⟶ { Alcohol, carbon dioxide }

Neubauer and Fromherz (1911) explain the decomposition of phenylamino acetic acid to benzylalcohol by the following series of reactions:

(A) $R.CH\,NH_2.COOH + O \longrightarrow R.C(OH)\,NH_2.COOH$ (Oxidation)
(amino acid) (hydrate of imino acid)

(B) $R.C(OH)\,NH_2.COOH \longrightarrow R.CO.COOH$ (Desaminization)
(hydrate of imino acid) (keto acid)

(C) $R.CO.COOH \longrightarrow R.CHO + CO_2$ (CO_2 splitting)
(keto acid) (aldehyde)

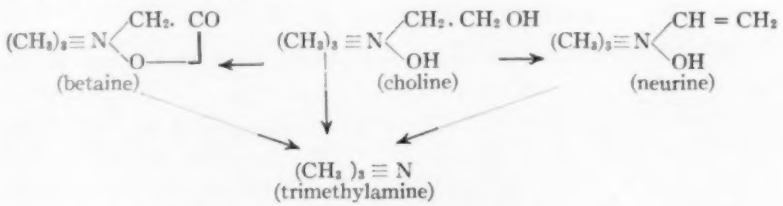
(D) $R.CHO + H_2 \longrightarrow R.CH_2\,OH.$ (Reduction)

A combination of a number of these reactions may be brought about by a single organism, and different results may often be obtained using the same organism under varying conditions.

In addition to these reactions, as has already been mentioned, arginine may be split into ornithine and urea by the enzyme arginase. There exist in the soil many organisms which are capable of decomposing urea with the formation of ammonia.

Ruata and Caneva (1901) found that lecithin, a phosphoglyceride found in conjugated proteins in many cells, may be split by bacteria into choline, glycerolphosphoric acid and fatty acids. Hasenbrock (1888) and also Ackermann and Schütz (1911) have shown in turn that choline decomposes during putrefaction into ammonia, trimethylamine, carbon dioxide and methane. It is interesting in this connection to note that both choline and trimethylamine have been found in soils.

Trimethylamine is also a decomposition product of betaine, which is found widely distributed in plants. Another substance found in putrefaction, closely related to choline, which yields trimethylamine on decomposition is neurine. The relationship between these compounds may be best represented by presenting their structural formulas:



Another methylated compound which has been found in plants and animals and in the soil is creatinine. This compound contains

the guanidine nucleus, which is also present in arginine. Reisser claims that creatinine is formed in the organs from either choline or betaine and urea. Twort and Mellanby (1912) have shown that numerous bacteria are able to decompose creatinine, ammonia being one of the products.

Guanidine, which has not as yet been found in soils, has been shown to be a constituent of molds and may arise by the decomposition of arginine. This compound, which is very toxic to wheat seedlings, has been found by Ulpiani and Cingolani (1905) to be a decomposition product of bacterial action on guanine, together with urea and carbon dioxide. Bierema (1909) has further shown that by the action of bacteria guanidine yields ammonia.

The fact has already been mentioned that the purines are acted upon by enzymes of a desaminizing and oxidizing character so that ammonia is formed. Uric acid, which also belongs to this class of compounds, has been extensively studied in this connection and it has been found to be readily ammonified.

The reactions cited above are some of the most important ones taking place in the soil connected with the phenomenon called ammonification. The above exposition shows that the process of ammonification from the biochemical viewpoint is extremely complex, and that it is most intimately connected with the process of the decomposition of the protein materials in the soil. However, since the process is susceptible of so many variations, the course of the decomposition cannot be foretold by the simple observation of the amount and rate of ammonia formation. It is also evident that from the same materials under certain conditions of bacterial activity one type of organic compound will be formed, while under other sets of conditions other compounds will result.

SYNTHETIC PROCESSES IN THE SOIL.

While destructive processes are taking place in the soil at all times, synthetic processes are going on as well. To the synthetic processes belong those brought about by the agency of the microorganisms and other living matter in the soil, excluding the higher plants. While these organisms decompose the nitrogenous materials in the soil, they, in order to sustain life and growth, build up protoplasm. The protoplasm of microörganisms has been found to consist to a greater or less extent of proteins,

depending somewhat upon the nature of the media upon which the microörganisms have grown. Substances resembling proteins have been isolated from the bodies of bacteria, molds, and yeasts, but these have not been prepared in very pure condition. There is also evidence to show that a fairly large proportion of nucleic acid is present in microörganismal protoplasm; indeed several nucleic acids have been isolated from this class of material and the constitution of these has been pretty clearly defined. By hydrolysis of the bodies of bacteria and molds a number of amino acids have been isolated, but aside from this not much is known concerning the chemical composition and structure of the proteins contained therein. The mycelium of molds is said to be rich in lecithin, in addition to proteins and nucleic acids.

In regard to the nitrogen compounds which are present in the protoplasm of soil organisms, Omelianski and Sieber (1913) report that the bodies of Azotobacter chroococcum contain about 13 per cent. of nitrogen, which by analysis, according to the Van Slyke method, they found to be distributed as follows:

Amide nitrogen 9.6, melanin nitrogen 3.5, arginine nitrogen 10.13, histidine nitrogen 1.64, lysine nitrogen 14.60, monoamino acid nitrogen 55.40, and non-amino nitrogen 4.86 per cent., respectively, of the total hydrolysable nitrogen. The composition of other organisms would differ, since it is well known that the proteins of many organisms are specific. It would appear, furthermore, that the protein thus synthesized by microörganisms is rather resistant to the agencies of decay in the soil. This is shown, for example, by the experiment concerned with the decomposition of dried blood in soils. It has been suggested by other investigators that the bodies of bacteria might possibly be resistant to decay in the soil, particularly to nitrification, due in part to the presence in them of considerable amounts of nucleoproteins and in part to the presence of "antienzymes," which would inhibit decomposition.

That other synthetic processes go on in the soil there can be no doubt, but their presence up to this time has not been proved. It may be well, however, to consider a few of those processes of synthesis not related to vital action which probably take place in the soil.

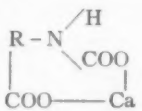
It is well known that there exist in the soil compounds which are related to the melanins, a class of poorly defined organic compounds. They are deeply colored, are generally high in carbon

content and low in hydrogen, and sometimes low in nitrogen. They are generally insoluble in acids and the usual organic solvents, many of them are soluble in alkalies and are precipitated as black or brown amorphous masses from alkaline solution on the addition of acids. To this class belong the compounds produced synthetically by Maillard (1913) by the interaction of amino acids and pentose or hexose sugars. As a contribution to the chemistry of these compounds may be mentioned the work of Gortner and Blish (1915), Gortner (1916), and Roxas (1916) who show that the humin or melanin nitrogen formed on the hydrolysis of certain proteins by mineral acids is chiefly due to the interaction of tryptophane and glucose, while tyrosine, cystine, arginine, lysine and histidine also contribute, but to a very minor degree.

It has been suggested that the nitrogen in such compounds exists in complex ring combinations and under such conditions is probably not easily subject to change in the soil.

Another type of chemical synthesis which may possibly take place in the soil is that which results in the formation of carbamino acids. Siegfried showed in 1905 that when carbon dioxide is passed into a solution of the calcium or barium salts of the monoamino acids that the corresponding salts of the carbamino acids were formed according to the following general reaction:

The calcium salt of this dibasic acid has the following structure:



This type of compound may also be formed in the same manner from the monoamino dibasic acids, the diamino acids, polypeptides, peptones and proteins. The calcium salts of some of these compounds are rather insoluble in water. We know that there are present in the soil the conditions necessary for the formation of such compounds since carbon dioxide is liberated in large

quantities during the decay of organic matter and, if not already present, lime is commonly added to soil to correct acidity.

From these examples an idea of the complexity of the compounds built up in the soil by purely chemical reactions is obtained. These synthetic processes are just beginning to be studied and may be of deep significance to soil fertility.

THE CHEMICAL METHODS OF EXAMINATION.

The chemical methods used in this investigation may be divided into two classes, (1) analytical and (2) isolation methods. It is not the purpose of the present paper to dwell at any length on the methods used, but for a clear understanding of the mode of attack and the problem at hand these will be described in principle. For the special details involved, particularly in the isolation and identification methods, the reader is referred to the original papers dealing with the isolation of these compounds from soils and from other material.

ANALYTICAL METHODS.

Total nitrogen was determined by the Kjeldahl-Gunning-Arnold method (Trescot, 1913).

Ammonia was determined by distilling in vacuum a mixture of the substance with a 10 per cent. solution of calcium hydroxide into N/10 sulfuric acid and titrating with N/20 sodium hydroxide, using alizarine red as an indicator.

Nitrogen Partition.—For the purpose of determining the forms of nitrogen resulting from hydrolysis of the protein materials the method described by Van Slyke (1911, 1912) was used. This method, which is based on the fact that amino groupings will react to form free nitrogen according to the formula:

$$R \cdot CH\,NH_2 \cdot COOH + HNO_2 = R \cdot CH\,OH \cdot COOH + N_2 + H_2O,$$

has proved to be extremely useful in biochemical work. Van Slyke (1915) states in a recent article that the method was designed only for use with pure proteins not accompanied by other classes of substances, particularly nitrogenous compounds. The presence of these would obviously render the interpretation of the results faulty unless the behavior of the nonprotein substances were so clearly understood that corrections might be made. It must be clear that during the decay in the soil of such

complex protein materials undoubtedly compounds other than proteins or the primary decomposition products of these must make their appearance. Just what these compounds may be we can but conjecture at this time, so that the results of the Van Slyke method when applied to the partition of the forms of nitrogen in the soil, while reported as lysine nitrogen, arginine nitrogen, etc., can only be considered approximations for the amounts of these various forms actually present in the soil in proteins or as primary decomposition products of proteins. It should be emphasized, however, that such a method is of decided value, even under such limiting circumstances, in attacking problems like those at hand, since by the use of such a method it is possible to divide the nitrogenous compounds present in the soil or fertilizer into a number of classes which react towards the various reagents involved in the analytical procedure as though they were arginine, histidine, etc. The very fact that a given nitrogenous compound will, towards a given chemical reagent, or a series of them, react like arginine, histidine, etc., establishes a chemical, and possibly a biochemical, relationship.

By the use of the Van Slyke method the nitrogen is divided into the following fractions: Amide nitrogen, melanin nitrogen, arginine nitrogen, histidine nitrogen, lysine nitrogen, monoamino acid nitrogen and non-amino nitrogen.

Moisture determinations were made by drying the soil samples in an electrically heated air bath for 2 hours at 103° C. All analyses are reported on an oven-dried basis.

METHODS OF ISOLATION AND IDENTIFICATION.

The methods which have been selected for the isolation and identification of the compounds discussed in this paper were originally designed for the isolation of these from plants, flesh, etc., where the interfering factors are not so great. When these methods are applied to soils, where both the mineral and organic matter are very complex, the interfering compounds are numerous and occur in such quantities at times that the compounds sought for are completely obscured. The various fractions finally obtained for the isolation of the nitrogenous compounds are always contaminated with coloring matter, resinous material, and other compounds, in part precipitated by the metallic salts

used or in part dissolved by the same solvents. Such foreign material must be eliminated by careful precipitation and repeated solution. This purification, which is sometimes almost impossible on account of the nature and quantity of the contaminating materials, often yields only extremely minute quantities of the pure compound. Moreover, the isolation methods must be varied for each and every soil, since the nature of the organic matter of each soil is not only different but the organic compounds are present in different proportions and combinations. Frequently a compound can be isolated by more than one procedure, but this can only be ascertained by experimentation.

Experience has shown that samples of at least 100 pounds of soil should be available for the isolation of organic compounds. The soil, in lots of about 40 pounds, was stirred for several hours with about 20 gallons of 1 to 2 per cent. sodium hydroxide solution in a large porcelain-lined kettle provided with a power stirring device. The stirrer was then removed, the soil allowed to settle, usually over night, and the solution was drawn off by means of a siphon. To the soil solution so obtained a suitable acid, depending on the ensuing procedure, was added until the silt and humus bodies were well flocculated. Providing the methods to be used would not be interfered with by large amounts of iron salts, the acid solution was then filtered through a filter press under pressure. If, however, iron salts would be objectionable, the solution was filtered through filter paper in the usual way. In either case after the filtered solution had been made exactly neutral with sodium hydroxide it was concentrated to a volume of 2 to 3 gallons in a vacuum pan, the temperature of the liquid not rising above 52° C. In this way large quantities of soil were easily and safely handled and a great deal of time saved.

The action of the weak alkaline solution is apparently to remove the resinous and similar material from the soil grains and to dissolve water-soluble material, as well as to form sodium salts with any of the acids which are present in the soil.

The acid filtrate, after neutralization, was used for the isolation of the nitrogenous compounds.

The Purine Bases and Creatinine.—The original soil extract was made acid with sulfuric acid, and after filtering and concentrating was made quite alkaline with sodium hydroxide and the precipitate, consisting largely of the hydroxides of iron and alu-

minum, filtered from the solution. The bases were then precipitated by boiling with Fehling's solution and a little dextrose. The copper precipitate, after thorough washing with sodium acetate solution and then with alcohol, was suspended in water and decomposed with hydrogen sulfide, and after the sulfides were removed by boiling and filtering, the solution was concentrated to about 150 c.c. Small portions of this solution were tested for the presence of the purine bases and for creatinine by the following color reactions: (1) The Xanthine reaction, which is given by xanthine and guanine, (2) Weidel's reaction, which is given by xanthine and guanine, (3) Kossel's test, which is given by xanthine, hypoxanthine, guanine and adenine, (4) Jaffe's reaction, (5) Weyl's reaction and (6) Salkowski's test, all three of which are given by creatinine.

If the three color reactions were positive for *creatinine* in the solution tested, zinc chloride and sodium acetate were added to a portion of the solution and allowed to stand for several days, when the characteristic crystals of creatinine zinc chloride were formed. These were collected on a porous plate, washed with a little cold water, boiled with a little freshly precipitated lead hydroxide, filtered, and the filtrate concentrated to a small volume; on standing for several hours crystals having the characteristic form, solubility and color reactions of creatinine were obtained.

The remaining portion of the solution containing the purine bases was made ammoniacal and the bases precipitated with ammoniacal silver nitrate. The precipitate was filtered off, washed well with cold water, boiled with nitric acid (sp. gr. 1.10), and the solution filtered hot. On standing, if hypoxanthine, adenine or guanine were present, they separated out in the form of their silver nitrate salts, while the xanthine remained in solution. The crystals were filtered off, decomposed in boiling water with hydrogen sulfide and after the sulfides were removed ammonia was added to the solution, when *guanine*, if present, separated out and was filtered off. The precipitate was washed with a little cold water and was then dissolved in a little warm dilute hydrochloric acid. The guanine was then identified by means of its color reactions, and its characteristic salts, of which the picrate, described by Capranica, and the dichromate described by Wulff, are perhaps the best.

The filtrate from the guanine, which contained both hypoxan-

thine and adenine, was treated with picric acid, when the *adenine*, if present, was precipitated as adenine picrate. This was filtered off, washed with a little cold water, taken up in a solution of a little dilute hydrochloric acid, the solution shaken out with ether, made alkaline with sodium hydroxide, and the adenine precipitated as the copper salt, with Fehling's solution and dextrose. After treatment of this precipitate with hydrogen sulfide the adenine was further identified by the formation of its various characteristic salts—the hydrochloride, the nitrate, the dichromate, the picrate, and the platinum chloride.

The filtrate from the adenine picrate was treated with dilute sulfuric acid, extracted with benzol to remove the picric acid, and then precipitated in ammoniacal solution with ammoniacal silver nitrate solution. This precipitate, after washing, was decomposed with hydrogen sulfide, and after being freed from sulfides and after evaporation the *hypoxanthine* was identified by the formation of the hydrochloride, the nitrate, the platinum chloride, and the silver picrate salts.

The *xanthine* portion from the nitric acid treatment was made alkaline with ammonia, and the resulting precipitate, after washing, was decomposed with hydrogen sulfide and the xanthine identified by color reactions, and by the hydrochloride, the nitrate, and by the crystalline form of the base itself.

Cytosine.—For the isolation of this compound sulfuric acid was also used to acidify the alkaline extract from the soil. The concentrated neutral solution obtained from the vacuum pan was filtered, made acid with sulfuric acid, an excess of mercuric sulfate solution was added, and the whole allowed to stand for 24 hours. The precipitate which formed was filtered off, washed well, and after being suspended in water was decomposed with hydrogen sulfide. When the sulfides had been removed the solution was evaporated to a small volume and allowed to stand for a time. A crystalline mass separated out, which was mixed with coloring matter and foreign material; consequently the solution was evaporated to dryness and extracted a number of times with absolute alcohol. The alcohol removed much of the coloring matter, and by repeated fractional crystallization from water a white compound was obtained which showed the characteristic crystalline structure and shiny appearance of cytosine. This compound was further identified by its solubility in water, alcohol, and ether,

and the preparation of the platinum chloride, hydrochloride, picrate, and potassium-bismuth iodide salts.

Nucleic Acid.—In this case acetic acid was used to acidify the alkaline soil extract, and the concentrated liquor was filtered hot. After cooling, a little more than an equal volume of 95 per cent. alcohol was added to the solution and enough hydrochloric acid to make the solution acid to about 5 per cent. After standing several days the precipitate was filtered off, washed with water, and dissolved in dilute sodium hydroxide solution. The nucleic acid was again precipitated by the addition of sodium acetate, hydrochloric acid and alcohol. The precipitate was filtered, washed and dissolved in dilute ammonium hydroxide. To this solution lead acetate was added to complete precipitation, and the precipitate was filtered off and washed thoroughly with water. The precipitate was broken up, after suspension in a large volume of water, with sulfuric acid, care being taken to avoid any excess of acid. From this solution the nucleic acid was again precipitated as before and the precipitate after thorough washing on the filter was dried. The compound so obtained was fairly light in color and was amorphous. A portion of it was boiled with concentrated hydrochloric acid and tested for pentoses with the phloroglucin and orcin tests, which showed their presence. Another portion was evaporated with magnesium nitrate, ignited, and the residue taken up with hydrochloric acid. The solution gave tests for phosphates, both with ammonium molybdate solution and with magnesia mixture. The remainder of the substance was boiled with hydrochloric acid, made alkaline with sodium hydroxide and the purine bases precipitated with Fehling's solution and dextrose. From this point the procedure was identical with that described under the isolation of the purine bases. The bases, however, were usually obtained in such small quantities that their individual identity could not be ascertained.

Diamino Acids.—The alkaline extract of the soil was made just acid with sulfuric acid and filtered. After concentration, the solution was made acid to about 5 per cent. and filtered hot. After cooling, phosphotungstic acid was added until precipitation ceased, when the solution and the precipitate were allowed to stand for several days. The precipitate was then filtered off and washed with dilute sulfuric acid solution which

contained a little phosphotungstic acid. The precipitate was carefully dissolved in 45 per cent. sodium hydroxide solution, using phenolphthalein as an indicator and adding at no time more than two drops of the alkaline solution. Water was then added until a volume of about 1000 c.c. was reached and barium hydroxide solution was added until the phosphotungstate acid was precipitated. After filtering off the barium phosphotungstate and barium sulfate, the solution was just neutralized with sulfuric acid and was then evaporated almost to dryness with barium carbonate in order to expel all of the ammonia. The residue was taken up in about 1000 c.c. of hot water and filtered, and the precipitate washed with hot water. The filtrate was placed in a large flask and treated while hot with solid silver sulfate, which was added slowly until the solution contained sufficient to give a yellow precipitate when a drop was removed and tested with a saturated solution of barium hydroxide. The solution was then filtered and the separation of the three hexone bases was carried out according to the method of Kossel and Kutscher (1900), by means of precipitation with baryta.

Lysine was identified by means of its manner of isolation, the formation of its picrate, hydrochloride, and platinum chloride salts and by the action of the base itself.

Histidine was identified by its manner of isolation, the formation of the characteristic dichloride salt, the formation of the picrolonate, and its color reaction.

Arginine was identified by the manner in which it was obtained, and by the formation of the acid and neutral nitrate salts, the formation of the copper nitrate salt, the picrolonate, and by the properties of the free base itself.

Monoamino Acids.—The filtrate from the phosphotungstic acid precipitate above was made alkaline with barium hydroxide in order to remove the sulfuric and phosphotungstic acids, and filtered. The filtrate was concentrated and nearly neutralized with sulfuric acid. This slightly alkaline solution, about 500 c.c. in volume, was treated by boiling with freshly precipitated copper hydroxide, and was then poured into about 3000 c.c. of 95 per cent. alcohol and allowed to stand over night in order that the insoluble mineral matter might settle out. The deep-blue alcoholic solution was then filtered, the insoluble salts dissolved in water, and reprecipitated by pouring into alcohol as before. The alcoholic

solutions were then combined and evaporated to dryness, the residue was taken up in hot water and the copper removed by treatment with hydrogen sulfide. After filtering from the copper sulfide, the solution, which contained considerable color, was boiled with animal charcoal. The filtered solution was made faintly alkaline with ammonia and treated with freshly prepared copper hydroxide, keeping the volume of the solution at about 1000 c.c. The solution was filtered from the excess of copper hydroxide and evaporated to dryness on the steam bath. The solid residue was then scraped from the sides of the dish and extracted in a Soxhlet extractor with absolute methyl alcohol until no further blue color was imparted to the alcohol.

Leucine.—The alcohol insoluble portion was dissolved in a large volume of boiling water and the copper removed with hydrogen sulfide. The solution was filtered, boiled down to a volume of about 50 c.c. and treated with ammoniacal lead acetate until no further precipitation took place. The precipitate was washed with 95 per cent. alcohol and was finally decomposed with hydrogen sulfide, after suspending in water. On concentration of a portion of this solution, the characteristic crystals of impure leucine formed. The crystals were redissolved in water and added to the original solution, which was boiled with animal charcoal until the color was removed from the solution. The leucine was then purified as before by the formation of the copper salt and the basic lead salt. On concentrating the solution obtained from this purification crystals of pure leucine were obtained. They were identified by their crystalline form, solubility, the fact that the leucine sublimed, the crystalline form and solubility of the copper salt, and by the color reactions with quinone.

Tyrosine.—The methyl alcohol solution of the copper salts was evaporated to dryness, and the residue taken up in water. The copper was removed with hydrogen sulfide and the solution boiled with animal charcoal. After filtering the solution was concentrated and the long silky needles of tyrosine began to separate out. The needles were filtered off and extracted with boiling 70 per cent. alcohol. The crystalline residue was recrystallized from water several times and dried on a porous plate. Tyrosine was identified by its crystalline structure, its solubility in water, alcohol, acetic acid, ammonia, by the preparation of the copper salt, and by the color reaction given with Millon's reagent, and the

color reaction of ferric chloride with the sulfonic acid prepared from tyrosine.

THE DISTRIBUTION OF PROTEIN DECOMPOSITION PRODUCTS IN SOILS.

In order to attain an adequate concept of the processes taking place in the soil and of the interrelations of the compounds occurring in soils it is not only necessary to isolate compounds from one soil but it becomes of importance also to study the distribution of such compounds in many soils. By such knowledge only does it become possible to formulate a rational theory as to the nature of the organic matter normally found in soils. It is advisable to know whether a compound is a constituent peculiar to the soil from which it was isolated or whether it is of general occurrence in soils. Does it appear in one and the same soil under all conditions, or is it the result of special treatments or farm practices? It is obviously of the greatest importance to know under what soil conditions and in what soils or class of soils any particular compound or group of compounds exists in order that a true and comprehensive view of organic matter in soils be obtained. In a word, it is necessary for the investigator interested in developing the science of agriculture from the standpoint of the relations of the biochemical and biological processes in the soil to the problem of soil fertility to be able to distinguish between what is normal to soils and what is abnormal. Therefore, a survey of the nitrogenous decomposition products of protein material occurring in a large number of soils from widely different regions was made.

THE SOILS STUDIED.

The results obtained on a number of samples of soil from different localities by the application of the methods of isolation and identification, which have already been described, are briefly given in the following paragraphs, the soils being grouped by States in which the samples were collected.

Maine.—Two samples of Orono clay from the vicinity of Oldtown, Me. In both samples histidine was found, and in one of the samples there was found, in addition, hypoxanthine.

Massachusetts.—Five samples from various parts of the Boston Common, Boston, Mass. All of these samples showed the presence of cytosine and hypoxanthine. These samples all represent different sorts of soil.

New York.—A sample of Volusia silt loam from Ontario, N. Y., showed the presence in the surface soil of cytosine, histidine, choline,[1] creatinine,[2] nucleic acid,[2] and in the subsoil hypoxanthine was found in addition to cytosine and histidine.

A sample of Clyde loam from Orleans County, N. Y., contained in the surface soil histidine, cytosine and hypoxanthine. The sample of subsoil showed in addition to these compounds the presence of xanthine.

The examination of a muck soil from Orleans County, N. Y., showed in the upper as well as in the lower layers the presence of histidine.

A sample of Dunkirk clay contained creatinine.[2]

Pennsylvania.—A sample of Chester silt loam from near Philadelphia, Pa., showed the presence of cytosine, arginine, xanthine and hypoxanthine.

A sample of Frankstown stony loam from Bedford County, Pa., contained histidine and creatinine[3] in the surface soil and histidine in the subsoil.

Maryland.—A sample of Elkton silt loam from near Easton, Md., contained nucleic acid, xanthine, adenine, histidine, and creatinine.

A sample of Sassafras silt loam from the same field contained nucleic acid, hypoxanthine, histidine, and creatinine.

West Virginia.—Samples of both surface and subsoil of Dekalb silt loam from the vicinity of Ravenswood, W. Va., showed the presence of histidine.

Kentucky.—A sample of Clarksville silt loam from near Broadhead, Ky., showed the presence of histidine and creatinine.[3]

Mississippi.—Investigations on a sample of Houston clay from Nuxobee County, Miss., showed the presence of histidine[4] and arginine.[4]

Texas.—A sample of Amarillo silt loam from Sherman County, Texas, showed the presence of histidine in both surface soil and subsoil.

North Dakota.—A sample of Marshall clay from Fargo, N. D., showed the presence of arginine,[3] histidine,[3] and cytosine.[3]

[1] Shorey, 1913.

[2] Shorey, 1912, i, ii.

[3] Shorey, 1912, i.

[4] Schreiner and Shorey, 1910.

California.—From a sample taken from an orange grove near Riverside, Calif., lysine [1] and nucleic [1] acid were isolated.

Georgia.—From a salt marsh near Brunswick, Ga., trimethylamine [1] was isolated.

Connecticut.—From a soil from near Redding, Conn., adenine [1] was isolated.

The occurrence of these decomposition products of proteins and nucleoproteins in many soils may be summarized as follows:

Histidine, arginine and lysine, the three hexone bases, are primary decomposition products of proteins. Histidine was found in eighteen of the twenty-four soils examined for its presence; arginine was found in but two soils and lysine in but one. This indicates that histidine is a fairly common constituent of soils, and shows, therefore, that the protein cleavage in the soil is of the same nature as that brought about in the laboratory. It further shows that histidine is quite resistant to bacterial decomposition. Arginine and lysine which are also present in almost all proteins seem to be not so common to soil organic matter; they are no doubt formed in the soil, but unlike histidine, their nitrogen is contained in chain linkage and not in ring formation and they are therefore more easily subject to decomposition in the soil.

Nucleic acids were isolated from four of the soils examined for them.

The three purine bases, adenine, xanthine and hypoxanthine, and the pyrimidine base, cytosine, are products of the biochemical decomposition of nucleic acids. Hypoxanthine was found in twelve of the twenty-four soils examined; cytosine was also obtained from twelve of the soils. These two bases were found associated in eight of the twelve soils. Xanthine was found in four of the twenty-four soils and was associated with hypoxanthine in three of these. Adenine was found in but two of the soils and was associated with xanthine in one of these.

Hypoxanthine and cytosine seem to be more resistant to bacterial action in soils than the other purine and pyrimidine bases, and this may explain their more frequent occurrence. Xanthine is rather easily oxidized to uric acid and this is easily decomposed in the soil. Adenine is changed by desaminization into hypoxanthine and this may explain the more frequent occurrence of hypoxanthine in soils and the infrequency of the occurrence of

[1] Schreiner and Shorey, 1910.

adenine. Cytosine and hypoxanthine seem then to be normally occurring soil constituents, being found in about half of the soils examined for their presence; xanthine occurs less frequently than these, and adenine only to a limited extent.

Creatinine has been found in six of the ten soils examined for it and seems to be a regularly occurring soil constituent, likely to occur in all soils.

Choline and trimethylamine have each been found in but one soil, but no survey has been made for the distribution of these compounds. It is quite likely, however, that their occurrence is not usual in soils.

Tetracarbonimid has been isolated from a soil from Virginia. A compound having similar properties has been obtained from several other soils in Florida and Maryland but in such small quantities that its identity could not be established as tetracarbonimid. (Shorey and Walters, 1914.) Owing to the very similar properties of cyanuric acid it is uncertain whether this compound is tetracarbonimid or cyanuric acid.

Cyanuric acid has been reported as having been isolated from five soils examined for its presence; soils from Indiana, Florida, Maine, District of Columbia, and Texas. It is uncertain in the light of our present knowledge whether cyanuric acid or its isomer cyamelid occurs as such in soil. (Wise and Walters, 1917.)

The presence of urea in forest soils, truck soils, humus soils, and virgin soils of France has been reported by Fosse (1916).

(To be continued.)

THE EQUIVALENT MASS IN RIGID DYNAMICS, WITH APPLICATIONS TO GYROSCOPES AND SCREW PROPELLERS.*

BY

A. F. ZAHM, M.E., Ph.D.,

WITH DIAGRAM AND DATA BY

W. P. LOO, M.S.

PREFACE.

In the analysis of the motion of a rigid body, the forces acting upon it may be replaced by three component forces acting along the principal axes through its centroid, and three component couples acting about those axes. Then the translation of the centroid is determined from the mass and three component forces; the rotation about the centroid is determined from the principal moments of inertia and the component couples. From the original given forces, therefore, the entire motion of the body can be found if its mass and principal moments of inertia be known, even though the shape and distribution of mass be disregarded or unknown.

THEORY OF EQUIVALENT MASS.

In analyzing the motion of any given rigid body, it is always possible, and sometimes more convenient, to employ in place of the actual body a kinetic equivalent, that is, a mass distribution which would, under the given system of forces, have the same translation and rotation as the actual body. For example, suppose the given body to be specified by mass M and principal moments of inertia A, B, C, and choose for equivalent body the point-mass distribution shown in Fig. 1, and defined by the following equations in which a, b, c, are distances from the origin of the equal point-masses M/6.

$$\left.\begin{aligned} b^2+c^2&=3\ A/M \\ a^2+c^2&=3\ B/M \\ a^2+b^2&=3\ C/M \end{aligned}\right\} \text{-------- (1)}$$

Then, since the right members are given, the massless arms a, b, c, and hence the required space distributions, are fully determined, providing the arms be real.

* Communicated by the author, September, 1916.

To show that a, b, c, are always real, note from equation (1) that $a^2 = \frac{3}{2M}(C-A+B)$, so that a cannot be imaginary unless A be greater than C + B. Now, if m be any particle at x, y, z, of any rigid body,

$$\left.\begin{aligned} A &= \Sigma\, m\,(y^2+z^2) \\ B &= \Sigma\, m\,(x^2+z^2) \\ C &= \Sigma\, m\,(x^2+y^2) \end{aligned}\right\} \text{-------- (2)}$$

Hence, $a^2 = \frac{3}{2M}(C-A+B) = \frac{3}{M}\Sigma\, mx^2$, which is always positive, *i.e.*, a is always real. Similarly b and c are always real. Writing $\Sigma mx^2 = Mx_1^2$ gives $a = \pm\sqrt{3}x_1$; similarly $b = \pm\sqrt{3}x_1$ $c = \pm\sqrt{3}z_1$, where x_1, y_1, x_1 are the radii of inertia referred to the principal planes.

In the most general case of rotation about three axes, each particle of the six-point equivalent mass exerts a gyroscopic torque whose magnitude and direction may be found by the method employed for a single gyroscopic particle. The component torques so found can be compounded in the usual way to obtain the resultant torque.

A six-point equivalent mass has been used here as a convenience; other distributions comprising fewer or more particles may obviously be employed.

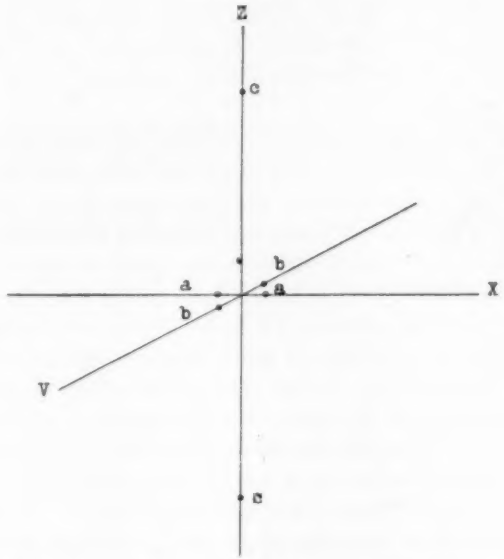
Examples.—As illustration, suppose the model to represent a gyroscope rotating steadily about two axes only, say X and Z, its centroid being either stationary or in motion. Then the masses at a, a, taken together obviously exert no resultant moment, for they have no gyroscopic acceleration, and any acceleration they may have from their translatory motion is, in magnitude and direction, the same for both. From this it follows that such a rigid body has the same gyroscopic torque whether its mass be all in the plane of rotation Y Z, or not; that is, whether a be zero or of any finite magnitude. Hence the gyroscopic torques about Y and Z, of any rigid solid rotating about X and Z may be derived from the treatment of a point mass distribution in the Y Z plane, say four equal particles spaced as shown in Fig. 1, at b, b, c, c.

It has been proved elsewhere [1] that a single particle of a gyro-

[1] *Aerial Age Weekly*, September 25, 1916.

scope in steady [2] rotation and precession has about the nutation axis a torque proportional to the sine square of its angular distance from that axis. Four equal particles symmetrically placed about the rotation axis have, therefore, about the nutation axis a resultant torque which is constant and equal to twice the maximum torque of one particle. Hence any mass having kinetic symmetry about the rotation axis, since it is the gyroscopic equivalent of a four-particle mass, has a constant torque equal to twice the

FIG. 1



Mass-equivalent of Curtiss two-blade air screw. Diameter, 8'-6", Mass, 42 lbs., a=3.9 in. b=4.24 in., c=34.2 in.

maximum of one such particle. This generalization can, of course, be derived algebraically from the above mentioned sine square law. For example, it can thus be shown that n equal particles or radial lines symmetrically spaced about an axis have, if n exceed 2, a constant gyroscopic torque which is n/2 times the maximum for one particle or line.

[2] This restriction was merely a convenience. It is well known that the gyroscopic force and torque of any given body are the same for any specified angular velocities whether the motion be steady or accelerated.

Summary.—The foregoing treatment of the mass-equivalent of a rigid body may be summarized as follows:

Every rigid body has a mass-equivalent whose motion under given forces is the same as that of the body itself. In particular, any rigid body has as mass-equivalent six equal particles suitably placed on its principal centroidal axes and invariably connected by massless bonds.

A six-particle mass-equivalent reduces to four particles for a plane distribution; two for a rectilinear. The arms of the six particle mass-equivalent of any rigid body equal respectively its radii of inertia referred to the reference planes, multiplied by $\sqrt{3}$.

The gyroscopic torque about its centroid of any rigid body is unaffected by its linear or angular acceleration or by the linear speed of its centroid.

At any instant the gyroscopic torque of a rigid body is the resultant of the torques of its equivalent mass particles.[3]

Application.—Fig. 1 shows the equivalent mass, derived from experimental data, for a standard Curtiss two-blade propeller. From this figure we can judge the comparative gyroscopic value of the distribution of the propeller mass in each of the three axial directions, since this value varies as the square of the arm lengths, a, b, c, and as the products in pairs of the angular velocities, ω_x, ω_y, ω_z, about those arms. In fact the ratios of the three maximum gyroscopic torques of the pairs of point-masses are as $c^2\ \omega_x\ \omega_z : b^2\ \omega_x\ \omega_y : a^2\ \omega_y\ \omega_z$. In practice the angular velocities may have the values 150, 0.5, 0.5 radians per second, thus making the two largest torque ratios $c^2\omega_x\omega_z/b^2\omega_x\omega_y = 65$, and $c^2\omega_x\omega_z/a^2\omega_y\omega_z = 23100$. The resultant of the three component torques is at most, therefore, only $\sqrt{1+(1/65)^2+(1/23100)^2}$ times the major one, that is, about one-eightieth of one per cent. greater. The gyroscopic value of such a propeller, so running, may therefore with great accuracy be equated to that of a pair of simple particles.

[3] As is well known, the gyroscopic torque of any particle equals its angular momentum times its deviation or the rate of angular change of its plane of rotation.

THE PRODUCTION OF LIGHT BY ANIMALS.*

BY

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LIGHT PRODUCTION BY THE ELATERID BEETLES.

THE elaterid beetles are a group of elongate forms found all over the world and commonly known to English-speaking people as "spring-beetles," "snap-beetles," or "jumping-beetles." No less than 2700 species are known from various countries. Of the nine genera mentioned by Leunis, one, the genus Pyrophorus, has the power of lighting. Almost one hundred species of this genus are found in tropical America varying in size from a few millimetres long up to others that attain a length of over four centimetres.

The commonest and best known of these is *Pyrophorus noctilucus*, a brown-colored beetle about 3.2 centimetres long (see Fig. 1). It flies about at night emitting bright blue-green or greenish flashes and remains inert under bark or leaves in the daytime. It is used as a plaything by children or even as an ornament in the hair by ladies, and can be gathered in large numbers when the height of its breeding season is on. Its larva is a very different appearing creature, being very long and very thin in the dorso-ventral direction, of a light cream color with a dark brown head and jaws, these latter strong and used to bore its way through roots of the sugar cane in which it lives and on which it is reported to feed (see Fig. 2). Other observers report it to be a predatory form, living on other animals.

The elongated body of the adult insect shows three large and distinct light organs. Two of these show round or slightly oval spots of about 1.5 mm., symmetrically placed on each side of the upper surface of the thorax toward its posterior end. Fig. 1 shows these organs. The third is a single median organ placed on the anterior ventral surface of the abdomen and is partly covered by the thorax when the insect is at rest. In shape it is an irregular heart-shaped area in the female (see Fig. 3) and a much larger organ with wide reaching lateral wings and with its anterior

* Continued from page 94, vol. 183, January, 1917.

edge marked by one median and two symmetrical lateral notches which partly mark it into four lobes (see Fig. 4) in the male. Over both thoracic and abdominal organs the chitinous covering of the body is of a clear and transparent yellowish color plainly

FIG. 1.

Drawing of the luminous beetle, *Pyrophorus noctilucus*. One flying and one resting on a twig. Shows the two thoracic light organs and the single abdominal light organ. After Mangold.

showing the white color of the deep reflecting layer. On all other parts it is dark brown, so that the luminous organs stand out plainly to the eye when the animal is examined in daylight or lamplight.

FIG. 2.

Young larva of the luminous beetle, *Pyrophorus noctilucus*. After Dubois.

The manner of illumination is interesting. Ordinarily, when at rest or even most of the time while flying, the creature shows no light at all. If a resting beetle is seized in the hand and annoyed by rubbing or pressing, a clear greenish light appears in the two

thoracic organs, slowly attaining a maximum brightness and glowing until the annoyance has ceased, when it slowly dies away. During this time the abdominal organ shows no signs of light.

Only while flying in the breeding season does this larger organ come into play. Then, as the insect flies in swift lines and circles around the shrubs and palm trees, it gives repeated long flashes

FIG. 3.

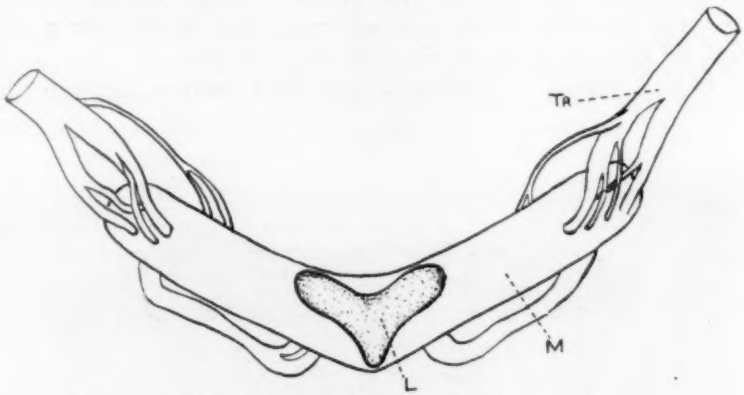


Diagram of a dissection of the abdominal light organ of the female *Pyrophorus*. *m*, muscles; *l*, light organ; *tr*, tracheæ. After Geipel.

FIG. 4.

Diagram of a general dissection of the abdominal light organ of the male *Pyrophorus*. *l*, light organ; *tr*, tracheæ. After Geipel.

with its abdominal light organ. The flash is very bright and on account of its lasting quality gives the eye an impression of a streak of light rather than a single flash. This flash is said to be yellower or redder than the flash of the thoracic organs.

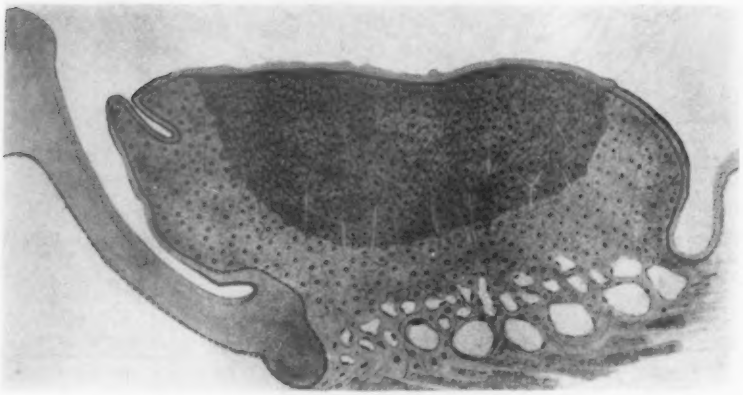
If the abdomen of a living specimen is cut off or torn from the thorax the organ may light, but usually does not. If the separated abdomen is gently pressed and released several times to bring about artificial breathing, the light will appear at about the

fourth to seventh "breath." It can also be brought to lighting by stimulating the proper ganglion in the central nervous system with a needle, as can also the thoracic organs.

Dissection of the organs shows all of them to have essentially the same structure although they vary somewhat in morphological details. Each one consists of a thickened plate of two layers of cells lying parallel with and against the "window" of transparent chitin that marks the organ. Large tracheal stems approach the organ from each side and form by division a network of finer air channels through its substances.

Fig. 5 shows a vertical longitudinal section through the

FIG. 5.



Vertical longitudinal section under low magnification of the abdominal light organ of a male *Pyrophorus*.

anterior portion of the abdomen and will serve to show the general relations of the organ to its surrounding tissues. It can here be noticed that the entire organ forms a mass that protrudes slightly from the body and at the same time its point of origin is somewhat sunken so that its outer surface is, after all, on about the level of the rest of the surrounding surface. As can be seen in the figure the chitinous covering of the body is a thick tough one with the color appearing in its outer third. Immediately around the organ this dips sharply downward and at the same time becomes somewhat thinner. As it turns sharply upward to ascend over the surface of the organ it attains its very thin condition over the entire organ surface. In the ascending zone, and for a

short distance over the surface, it is thin, but it shows a dense black pigment on its outer surface. This pigment appears in life as a black outer rim to the entire structure. Immediately over the larger central portions of the organ the chitin is, as has been said, colorless and very thin. Its thickness is modified in places by irregularities of its outer surface as shown in the figure.

The chitin, both of body and organ, is lined on its inner surface by a layer of hypodermal cells, as in all arthropods. These cells are, in the adult beetle, very thin and evidently of no important function. They were much more vigorous looking and vital in staining power at the time when, in the pupa, they were engaged in forming and building up the cuticle. If anything, they are in better condition under the thin covering of the luminous organ than under the heavy chitinous layer on the rest of the body. They do not assemble to send sensory hairs through the covering of the luminous organ, as they do under the other parts of the shell.

Immediately under the hypodermis of the central part of the organ are to be seen the actual luminous cells. These form a strong regular mass about eighteen to twenty-six cells deep. Their size averages about 75–150 microns in diameter when rounded, but they show a strong tendency to become elongate in a proximo-distal direction. For the most part they are closely massed together and moulded to fit each other's forms but at some points they show a slight tendency to form strings or rows, several cells wide, that reach from the surface inward.

The cell is provided with a large round nucleus and its cytoplasm is dense and dark staining with most chromatic stains. Two sorts of structures are to be seen in this cytoplasm: First, a certain number of large clear vacuoles that are placed around the edge or in groups in one end of the cell; secondly, very fine branching channels that may run centripetally from the edge toward the nucleus or may appear to enter the cell at one end and run through most of its length. They remind one somewhat of the trophospongia except that they reach the surface of the cell and sometimes appear to leave it. Fig. 6 shows a portion of one of these cells under high magnification.

The cytoplasm seems to owe its dense compact nature to masses of closely packed granules which fill every part of it. These give it its staining power and undoubtedly are the secretion particles

of luminous material spoken of as luciferine or photogenin. In size they are much smaller than those shown by the various lampyrids. Heinemann has teased out these cells both with and without the addition of water and describes the contents as of two kinds, a smaller, hard, sharply outlined set of granules and larger droplets of an oily material.

The smaller granules show a decided brownian or molecular motion when discharged by a pressure of the cover-glass. Also, they then appear in two forms, the new one larger and apparently softer than the first, but without any more decided refractive properties.

The larger masses are globular like an oil and show strong surface tension and decided refraction of light which seems to determine them as an oil. When water is added the smaller two forms of granule soon swell and dissolve, which is not true of the larger ones. The nerves and air tubes of the luminous layer will be spoken of later.

Proximal of the luminous layer comes a layer of cells that form the reflector of the organ. This layer is somewhat thinner, especially in its middle, than the luminous layer, but it becomes nearly as thick at its outer edges. It is far wider than the luminous plate and its edges reach up around the ends of the latter and come in contact with the hypodermis and cuticle near the outer edge of the organ. It is at this point too that the dense black pigment is found on the cuticle.

The cells of this mass are singularly like those of the luminous layer in many ways. They are massed in much the same way and are of about the same shape. In size, however, they are a little larger while the nuclei are possibly a trifle smaller, although these nuclei vary in size to a much greater degree than in the case of the luminous cells. There are no vacuoles and no channels in the cytoplasm. The cytoplasm of these cells is filled with granules which we must consider as the reflective material of the layer. These granules are so like those found in the lampyridæ which have been carefully studied that we may assume for the present that they are of the same constitution, some form of a calcium urate. Here again Heinemann has made some careful studies that give us a good idea of their structure and chemical constitution.

Heinemann cut out the larger abdominal light organs of 186 large *Pyrophorus* and reduced them to an ash in a slow oven.

He then extracted with distilled water and again heated the insoluble remainder. The water-extracted solution was treated with hydrochloric acid, and bubbles, of carbonic acid gas probably, were given off. Further analysis showed traces of chlorine, phosphoric acid and potassium.

The unsoluble ash showed a mixture of calcium urate and potassium urate. Heinemann studied fresh reflector cells and notes the presence of two kinds of bodies in its cytoplasm. One of these is a non-crystalline granule and he identifies this as the calcium urate. The other is a smaller crystalline granule which he supposes to be the potassium urate. He attributes the phosphoric acid to some of the contents of the light cells and to the nuclei of all cells.

Heinemann was unable to see cell walls or nuclei in the reflector layer. This was due to the imperfect methods of his time and, as has been indicated, they are as easily seen and described as any other cells in the organ in properly cut and stained sections.

The writer has attempted to devise certain fixations and stains that would serve to determine a substance as luciferine or photogenin or not when this substance was being sought in an organ of unknown location in an animal that had been seen to light but whose light organs had never been described. Some of this work was tried on *Pyrophorus* and some ability was developed here to quickly show the granules of luciferine. This work is not of an exact chemical nature but purely rule of thumb to determine the presence of the material. In material fixed in Bouin, if eosin is used or a similar acid dye the luciferine granules take this dye very deeply. This method is not very diagnostic, however, as a large number of other materials also take it.

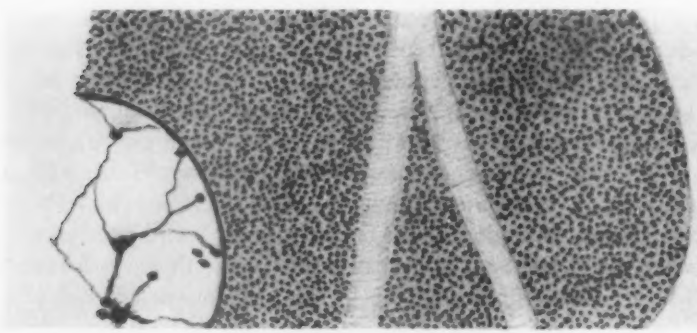
If the tissue is fixed in Flemming's fluid we get no very marked ability to distinguish the luciferine. But if hot Flemming's fluid is used and this is followed by an iron hæmatoxylin stain the granules of luciferine or photogenin come out quite black and can be differentiated from nearly all other substances in the body.

Thus Fig. 6 shows a small portion of the cytoplasm of a light cell in *Pyrophorus* stained in this way and exhibiting the small dark granules of light producing material. These granules remain and burn *in situ* and are undoubtedly in contact with the second substance or assisting medium while they do not burn and give off light solely on account of a lack of oxygen.

The light is produced as a long flash or more steady glow by

the admission of atmospheric air through the tracheoles that form a network through the tissue. These tracheoles are ultimate branches of the trachea that are formed of tube-like invaginations of the hypodermis and its attendant cuticle from several points on the sides of the body. The walls of the resulting ingrowing tube retain both the hypodermis in a flatter form and the cuticle as a much thinner secretion of this hypodermis. In order that the tube of the chiten and its branches may be thin and yet not collapse when the expiration of air takes place, it is lined by circular or spiral thickenings or tænidia which serve to keep it round in form. Larger branches of these trachea come to the luminous organ when they form a mass of good-sized tubes directly behind it. There

FIG. 6.



Portion of a light cell of *Pyrophorus* under high magnification, a part of the nucleus is shown and the granules of photogenin.

are reservoirs as well as conductors of the air and they give off numerous finer branches that pass down through the reflector layer and terminate in the luminous layer. They terminate by branching into a few long thin tracheoles that wind about between the light cells. These tracheoles have no tænidia but are long and smooth on the inside. They serve to carry the oxygen of the air directly to the light cells and their granules. No special structures mark the final branching of tracheal tube into tracheal capillaries. It is certain, however, that an unusually large amount of oxygen escapes into the tissues at that point, as is shown by forcing the insect to breathe osmic acid vapor, which also leaves the air passage through its thin walls at that point and blackens the surrounding tissue. Fig. 7 shows a section through this point.

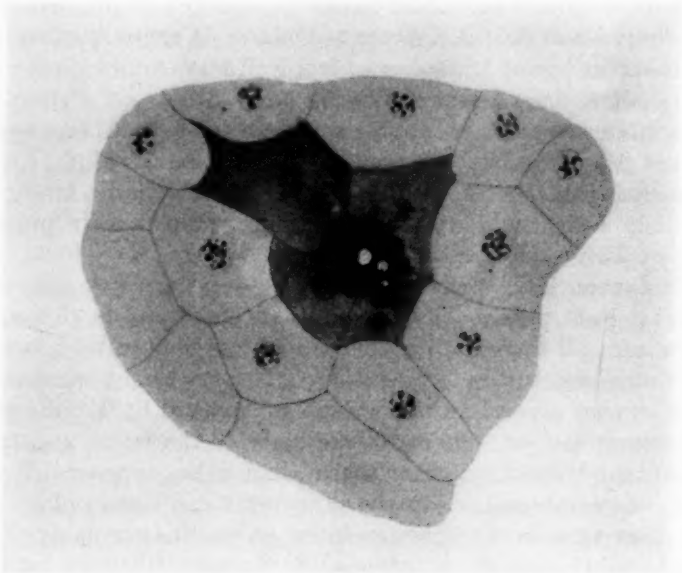
No very important chemical work has been done on *Pyro-*

phorus with regard to the chemistry of the light process and that will be left until the chapter on the lampyridæ.

Pyrophorus noctiluca lays its eggs shortly after mating and deposits them in dead wood and humus, according to Dubois who has studied their habits. Later observers assert that the eggs are always laid around or near the roots of the sugar cane on which the larvæ feed. This may be true of another species.

The eggs are luminous even before they are laid, as Dubois has

FIG. 7.



Section through branching tracheole at point where tracheal capillaries are given off. Dark cells have been stained by breathing of osmic acid. After Geipel.

described, and this light is weak and appears to come from all parts of the egg substance. When fertilized and laid they are still giving forth light. This light is not intermittent as in the adult, but is a weak, steady glow such as has been described in the bacteria and fungi. It was thought by some writers that the light came from the outside of the egg and that it was derived from some portion of the parent beetle's abdominal organ, but any knowledge of the insect's anatomy would easily show this to be impossible.

The light evidently emanates from the cytoplasm of the unicel-

lular ovum and represents a function of the organism that is not only already present in the one-celled stage, but one that exists in the cytoplasm of that egg and is already sufficiently differentiated to be operative at this early period. Such a delicate indicator might be of great use in studying the development of the organism and its differentiation.

As development proceeds the light gets fainter and we have no careful studies as to its intermediate fate. But just before hatching it is still visible and as the tiny larva crawls from the egg, the light is seen to come from a point inside the body and just behind the head. This observation cannot be doubted in the case of so well-known and skilful observer as Dubois. We now must mention the observations of a number of less well-known men on the subject. Many have asserted that the larvæ of several *Pyrophorus* species are without light. This may be true of some other species than *P. Noctiluca* but it is certainly not true of this kind. Others have described, insufficiently, certain luminous bettle larvæ that certainly were not *Pyrophorus*. Some of them were probably *Phengodes* larvæ or adult females and others were doubtful.

Returning to Dubois's observations we learn that the single anterior light persists through the first stage and in the second stage it is still there, but in addition he was able to see a number of other light organs in operation. The first eight segments of the abdomen showed each three brilliant spots of light, one median in position and two lateral. The body of the larvæ was translucent and Dubois said that the median lights appeared dimmer than the lateral ones and might have been a combined reflection of the other two on the shining chitenous wall of the body. This could easily be settled by sections which apparently were not used.

Dubois figured parts of a section of the single anterior light and from these figures it would appear that the structure was much the same as that of the adult organs. It was composed of a bilateral mass of cells about the intestine and these cells contained bi-refractive granules of some size.

A section through one of the posterior segments shows the two lateral organs as masses of cells held in a rounded evaginated pocket of the cuticle. No intimation of a separation into reflector and luminous layers is given and as the lower median portion of the section is missing one can make no surmise as to the presence or structure of the median organ of the segment as mentioned above. It seems probable that one was present.

INDEPENDENT LABORATORIES IN THE ENGINEERING INDUSTRIES.*

BY

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THE importance of laboratory work in connection with our national industries is coming more and more to be recognized, and there is no little discussion at the present time of suitable ways and means for promoting it. With the sharpened competition which must ensue at the close of the war which is now paralyzing the peaceful industries of the world, any and all means for increasing our industrial efficiency will be considered with a seriousness which in the easy-going times of the past has not been accorded to them.

Our great manufacturing organizations are for the most part quite awake to the fact that laboratory testing and research are necessary and indispensable adjuncts to the growth and development of their industries. They realize that it is to the laboratory that they must look for radical or fundamental advances in the materials, methods and processes of production. They have established splendid laboratories and have attracted to them some of the greatest scientific men of the country. The product of these laboratories has been of enormous value—a value which cannot be measured in money, for it includes engineering and scientific discoveries which become the permanent possession of the human race and add to the prosperity and happiness of all future generations.

The manufacturers of smaller resources do not, however, make a correspondingly large use of laboratory assistance. This may be ascribed to two causes: first, that they are not so fully aware of their own need for laboratory assistance and of the possibilities of laboratory work in increasing their efficiency, bettering their product and broadening their scope; and second, because of practical difficulties in securing such laboratory facili-

*Communicated by the Author.

ties as correspond to their needs. It is with the latter phase of the situation that this paper is intended primarily to deal.

Laboratory or research work is commonly divided into two classes, both of which are important in connection with our national industries. First, there is the work in pure or academic science—the work primarily of the university. Second, there is the work in applied science, or in industrial research. Dr. J. J. Carty [1] in his address as President of the American Institute of Electrical Engineers, has very clearly and very aptly drawn the distinction between research in pure and in applied science when he said that it lies neither in the subject matter, which may be identical, nor in the methods, which may be the same, but in the motive. To quote his words:

"Industrial research is always conducted with the purpose of accomplishing some utilitarian end. Pure scientific research is conducted with a philosophic purpose, for the discovery of truth, and for the advancement of the boundaries of human knowledge.

"The investigator in pure science may be likened to the explorer who discovers new continents or islands or hitherto unknown territory. He is continually seeking to extend the boundaries of knowledge.

"The investigator in industrial research may be compared to the pioneers who survey the newly discovered territory in the endeavor to locate its mineral resources, determine the extent of its forests, and the location of its arable land, and who in other ways precede the settlers and prepare for their occupation of the new country."

Evidently the industrialist who, to carry the analogy further, may be likened to the settler in the new territory, is dependent upon both classes of investigator; on the investigator in pure science because it is he who indicates the existence of a field heretofore unknown; on the industrial investigator because it is he who discovered the commercial possibilities which the field contains.

The organization which is pre-eminently fitted to carry on the primary work of pure scientific investigation is the university. It is to the university that we must look to discover and to foster the men having those rare and peculiar gifts of imagination, of transcendent patience, of unselfish devotion, which go to make up the explorer into the unknown regions for

[1] Carty, Proc. A. I. E. E., vol. xxxv, p. 1411, Oct., 1916.

the extension of physical and chemical science. It is the university which must furnish these men the surroundings and the facilities which are required for the prosecution of their work.

For the adequate pursuit of industrial research work, however, it is necessary to look to organizations constituted differently from the university. Industrial research having as its end the accomplishment of a definite result of commercial value accruing primarily only to the promoter of the work, it is evident that an institution organized like the university primarily for an educational purpose, and supported largely by endowments or by public funds, cannot justly devote any considerable portion of its energy or of its resources to any purpose which is not for the benefit of the public at large. The technical schools in this respect are in the same class with the universities, with the important exception that a technical school is in general better situated for the conduct of industrial research work than is the university from the fact that its training is along industrial lines. Hence we find that many of the great industrial corporations in this country have, as has been said, met their own needs by establishing their own private industrial laboratories. For the industries at large, however, this affords no adequate solution of the laboratory problem, for it does not apply to the multitude of concerns, individually smaller than the great corporations and unable each by itself to support economically and efficiently an adequate laboratory, but in the aggregate of enormous industrial importance. The importance of laboratory work to the smaller concerns is relatively just as great as to the larger ones, and the problem is, the best means of supplying their needs in this particular.

One possible solution is for the smaller manufacturer to take his laboratory problems to a technical school for solution. This plan, while it may work out admirably in many cases, is open to the objection which has been mentioned above, namely, that the funds of the institution, being given for a public purpose, should not be diverted to private ends. However, it may be urged against this that it is to the advantage of the technical school to take on a certain amount of industrial work, not only in research but also in testing. Such work necessarily brings both instructors and students into contact with certain practical problems of the outside industrial world, a world of which they know much in theory but too often but little in practice. The effect of this

contact cannot but be broadening and helpful to the technical school and to its students, and if this advantage is sufficiently substantial, the theoretical disadvantage of diverting the attention and the resources of the institution to a limited extent to matters which are particularly the affair of private outside individuals or corporations is more than counterbalanced. Added to this advantage to the technical school are certain others, among which may be mentioned that incidentally the frequently inadequate salaries of the body of instruction in the technical school are to some extent augmented and the instructors thereby put into a position more nearly in accord with the demands which are made upon them. To the industrial concern a recourse to the laboratory of a technical school may offer the advantage of furnishing a service for a smaller expenditure than would be necessary if all of the overhead and incidental charges were included, which under similar circumstances a commercial organization would have to make.

As against the advantages so outlined there are certain disadvantages which must be given careful consideration and due weight. We have noted that taking on a piece of industrial work has the effect of bringing instructors and students into contact with practical industrial problems and thereby broadens their vision and increases their usefulness. To the industrialist, however who has a problem to solve, the very lack of contact with the actualities of practice very greatly lessens the value of the technical school as an organization for the accomplishment of his purpose. Every technical problem is surrounded by limitations and special conditions which may not from an academic standpoint appear to be of controlling importance, but which if not given their practical weight render any solution nugatory. Considerations of cost, of the intellectual and psychological limitations of workmen, of transportation, or market conditions, of company policy, of technical and commercial usage in the field—any or all of them may have their influence on the result. The technical school men, if less in touch with practice, are evidently at a disadvantage in the solution of problems involving these elements. The technical school, being organized and equipped for purposes of education and not for purposes of testing or industrial research, is frequently at a disadvantage on account of the limitations of its laboratory equipment, the amount of power, etc., available, and on account of

the lack of a business or technical organization especially designed to prosecute with directness, accuracy and engineering common-sense, industrial problems which it never was designed to handle. It must be remembered that while many discoveries are made by laboratory experiments on a small scale, many of these are not applicable to industrial exploitation for the reason that elements which in small-scale experimentation are of negligible importance, often become controlling factors when the scale is changed to correspond to practical production. A chemist in his laboratory may effectually close a flask with a cork; a similar procedure does not apply at all to a spouting oil well. He may evaporate to dryness a dilute solution for the purpose of recovering a small residue and never once think of the gas which he uses in the process. If he were dealing, however, with the same operation on a scale ten thousand times as big, the matter of fuel and of containing vessel might offer insuperable obstacles to commercial success. Small-scale experimentation teaches but little regarding the proper design of a switch to open a high-tension power circuit. Hence apparatus which is quite adequate for the small-scale work of the laboratory of instruction may be entirely inadequate when experiments are required looking toward the industrial application of a process.

In speaking of this feature of industrial work in educational institutions, Dr. Steinmetz [2] in a recent address said:

"Unfortunately this limitation of research work in accordance with the available facilities is not always realized, and especially educational institutions not infrequently attempt research work, for which industrial laboratories are far better fitted, while research work for which the educational institution is well fitted, which the industry needs but cannot economically undertake, is left undone."

Prof. James Swinburne [3] in a lecture on Science and Industry, delivered very recently at Kings College, has pointed out that the instructor in technology tends as times goes on to be less and less in touch with practical conditions and more of an academic scientist. This is for the reason that in general only those who have less taste for engaging in the practical work of industry are likely to take up the teaching profession, and their own successors

[2] JOURNAL OF THE FRANKLIN INSTITUTE, vol. 182, p. 711, December, 1916.
[3] *The Electrician*, London, vol. lxxviii, p. 182, November, 1916.

are as a general thing the less practical ones of their own students. The academic scientist, on the other hand, is a master of his subject, for his science, like himself, is academic, and in his own field he is pre-eminent. Thus the tendency of the technologist to become academic is a tendency for him to follow his own proper bent and to employ his energies in the direction in which they will be most effective.

Since to refer the problems of the industry to the technical schools for investigation does not offer a satisfactory solution of the problem, some other way out must be sought. This may be found along the lines indicated by Dr. Carty when he said:

"One of these is for the manufacturer to take his problem to one of the industrial research laboratories already established for the purpose of serving those who cannot afford a laboratory of their own. Other manufacturers doing the same, the financial encouragement received would enable the laboratories to extend and improve their facilities so that each of the small manufacturers who patronizes them would in course of time have the benefit of an institution similar to those maintained by our largest industrial concerns.

"Thus in accordance with the law of supply and demand, the small manufacturer may obtain the benefits of industrial research in the highest degree and the burden upon each manufacturer would be only in accordance with the use he made of it, and the entire cost of the laboratories would thus be borne by the industries as a whole, where the charge properly belongs."

Thus to the independent laboratory is assigned an important place in the engineering industries as providing for the smaller manufacturer laboratory facilities comparable with those enjoyed by some of the great corporations. To fulfil properly these functions the independent laboratory must be adequately supported, properly manned and abundantly equipped. Its staff must be organized on broad lines. Its engineers must be familiar with the practical and commercial features, as well as the technical details, of the work which they encounter. It must include physicists and chemists accustomed to look at the fundamental features of the problems presented and to bring to bear upon their solution the methods and the point of view which are inculcated in the university laboratories of research, for the application of fundamental scientific principles to the solution of the problems of industry

underlies all true industrial research. The fees charged by such a laboratory must be adequate to cover not only all expenses, but to yield a sufficient profit as well, for:

"Unless industrial research abundantly supports itself, it will have failed of its purpose."

In return for the fees so paid it must deal with its clients in a highly confidential manner, conserving to them individually all of the results of the work for which they are paying. It must be prepared to turn over to its clients the inventions and patents which are the direct outcome of any specific piece of work. It must organize its work efficiently, so that its costs are as low as is consistent with good work and so that the results are obtained without undue delay. As to equipment, this undoubtedly must be large. The variety of problems which a laboratory of this sort will have brought to it will be of such scope that a great variety of instruments for measuring and for manipulation must be at hand. A very large supply of electrical power is an absolute requisite. These conditions interpose serious obstacles in the way of the establishment of laboratories of this character. Unless the laboratory is organized through the coöperative efforts of a considerable number of industrial corporations operating in the same or in similar fields, a difficulty is sure to be encountered in insuring beforehand its proper support. To some extent a laboratory of this sort must from its very inception possess an equipment representing a very considerable investment. Unless therefore the financial support is insured beforehand, no little faith is required on the part of those investing their money in it. When, however, it has been possible to establish a laboratory of this character, the scope of its work may be very large. It may, and should, include not only industrial research proper, but ordinary and routine testing, such as is required not only by manufacturing concerns, but also by consulting engineers and others. It should be prepared to make acceptance tests of manufactured articles on behalf of purchasers and a considerable part of its activities may lie in this direction. It should offer facilities to engineers, inventors and other would-be experimenters to carry on laboratory work of their own under its roof, and should make available to them all its own facilities. In carrying out work of this great scope in an adequate and proper manner the independent laboratory will find itself side by side with the technical

school as one of the potent factors of industrial progress. The staff of such a laboratory will become increasingly efficient through the practical solution of problems of many kinds. The apparatus and other equipment will necessarily take on a diversified character such that new and unusual problems presented can be undertaken without the purchase or construction of special apparatus. As compared with under-equipped and insufficiently manned laboratories which with a most laudable spirit individual manufacturers may establish for their own use, independent laboratories, supported by formal or informal coöperation, should be far more efficient both as regards the cost of maintenance, the character and extent of the equipment, and as to the practical results to the industries, because of the product of the researches conducted therein. In the last analysis the availability and utility of such laboratories depend on the amount of material support which the industrial world is willing to accord to them.

A Method of Comparing Automobile Performance. W. T. FISHLEIGH. *Society of Automobile Engineers' Bulletin*, vol. xi, No. 2, November, 1916.)—The problem of analyzing automobile performance is not a new one and much has been written and argued upon the subject. The demand is widespread for a standard interpretation for performance and a method of determining it. Numerous formulas have been proposed. In most cases these are efficiency formulas, designed for estimating from certain known dimensions the probable performance or performance factors. In no case are all these factors included that seem critical in performance; in several cases serious inaccuracies can be pointed out when their application to actual road performance is attempted.

Automobile performance should be determined by actual tests, and *speed range, acceleration, fuel economy* and *riding comfort* are the factors for such determination. The first three of these factors are susceptible of measurement by accurate tests and the product of such factors would result in a satisfactory criticism of performance. It has been pointed out, however, that in taking the product, the identity of each one is entirely lost, and for purposes of comparison the limits rather than the maximum of these three factors should be separately considered as the three dimensions of car performance. The factor of riding comfort is one that scarcely admits of definite numerical expression.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

STANDARD SUBSTANCES FOR THE CALIBRATION OF VISCOMETERS.[1]

Eugene C. Bingham and Richard F. Jackson.

[ABSTRACT.]

For the purpose of the calibration of viscometers there is a need for one or more liquids of viscosity greater than water which can be easily obtained in pure condition and whose viscosity is known with a considerable degree of certainty. The substances selected, besides water, were mixtures of ethyl alcohol and water, and sucrose and water. Previous work upon water and alcohol was adequate and consequently the experiments were confined to the sucrose and water. The sucrose was purified by repeated recrystallization from water solution and contained residual impurities of the order of one-thousandth of a per cent. The solutions used in the measurements were analyzed by determination of density and by polariscopic test.

The viscometer used in the investigation consisted essentially of a U-tube fitted with a capillary on one limb surmounted by a bulb with constrictions which could be used to measure the volume of liquid. A bulb of similar size and shape was sealed on the other limb. The viscometer was connected to a manometer and pressure apparatus for the application of pressure. From the observations the viscosity was calculated by the usual formula

$$\pi = C\ p\ t - C'\ \rho/t$$

in which p is applied pressure, ρ density of liquid, t time of flow, C and C' constants abbreviated from the complete viscosity formula. C' was found by direct calculation, C by measuring the time of flow of pure water at 20° C. and substituting its viscosity 0.01005.

The viscosity was measured at a variety of applied pressures. To obtain the true effective pressure, the height of liquid in the manometer is corrected for air buoyancy, column of connecting

* Communicated by the Director. [1] Scientific Paper No. 208.

air and hydrostatic head of the liquid undergoing measurement. In order to be certain that the drainage of solution was complete the time of flow required to discharge and to fill the bulb was measured. Furthermore, viscosity was found to be independent of applied pressure. To test calculations and corrections the viscosities of water were measured, using a considerable range of pressures. The value was found to be constant.

In order to avoid the arbitrary scales of commercial viscometers and the inconvenient magnitudes of the absolute units, we suggest the use of the "centipoise" as a unit of viscosity. This is one-hundredth part of the C. G. S. absolute unit. The centipoise is almost exactly the viscosity of water at 20° C. (1.005) and, hence, is at the same time the specific viscosity of any substance referred to water at very nearly 20° C.

The viscosities of water have been determined by several investigators. The existing data has been reviewed in order to correct it so far as possible according to our present knowledge. The mean values expressed as fluidities may be expressed by the formula:

$$\phi = 2.1482 \left\{ (t - 8.435) + \sqrt{8078.4 + (t - 8.435)^2} \right\} - 120$$

in which ϕ is fluidity and t centigrade temperature.

Mixtures of ethyl alcohol and water may be used as standards. Their fluidities expressed as functions of temperature and weight and volume percentage of alcohol accompany the complete article.

The viscosities of a 39.99 per cent. sucrose solution were measured at temperatures varying from 0° C. to 95° C. The observed values corresponded to the formula:

$$t = 0.597\ (\phi + 20)\ - \frac{1438.6}{\phi + 20} + 38.24.$$

Inasmuch as some discrepancy was found to exist between this and former values the experiment was repeated and practically the same values were obtained.

The measurements were then made on 20.007 per cent. and 59.96 per cent. sucrose solutions. The fluidities at the latter concentration corresponded to the formula:

$$t = 1.472\ (\phi + 5) - \frac{323.2}{\phi + 5} + 58.62.$$

The values found in the present investigation indicated a higher viscosity than those of previous investigators.

THE MANUFACTURE AND PROPERTIES OF SAND LIME BRICK.[1]

By Warren E. Emley.

[ABSTRACT.]

SAND lime bricks are made of sand and lime, hardened by exposure to the action of steam at high pressure. They compete in numerous localities with common building bricks made of clay. There is a widespread demand for information as to just what sand lime bricks are, how they are made, and what properties one may expect them to have. In this paper an attempt has been made to compile this information and make it accessible. A short theoretical discussion leads to certain conclusions as to the desired properties of the raw materials—sand and lime. The different steps of the process of manufacture are then taken up in detail, and comparisons made of the different mixing, pressing, and hardening operations as carried on in various factories. The testing methods generally employed for the examination of common building bricks are described in detail, and a summary is given of the results obtained when sand lime bricks are subjected to these tests. An appendix contains detailed descriptions of the equipment of seven typical factories.

THE RESISTANCE OF AN OIL TO EMULSIFICATION.[2]

By Winslow H. Herschel.

[ABSTRACT.]

IN forced feed lubrication, such as is used with high speed engines and turbines, there is often trouble due to the emulsification of the oil. Service tests are not practicable, on account of the time and trouble involved, so that there is great need of a laboratory test. Moreover it is highly desirable that the test should make it possible to express the resistance of an oil to emulsification by a single numerical value, as experience has proved that it is almost impossible to enforce in a contract any less definite specification.

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[1] Technologic Paper No. 85.
[2] Technologic Paper No. 86.

A study of the literature showed that though several emulsification tests were described, they were all more or less indefinite, and no one of them was in general use. It was therefore necessary to devise an entirely new test, which may be briefly described as follows:

Twenty cubic centimetres of the oil to be tested, and double that volume of distilled water, are heated to 55° C. (130° F.) in a 100 c.c. cylinder, 26 mm. (one inch) inside diameter, and stirred for five minutes at a speed of 1500 r.p.m. The paddle is simply a plate of metal, 89 by 20 by 1.5 mm. ($3\frac{1}{2} \times 13/16 \times 1/16$ in.) approximately. Since the test is not sensitive to slight changes of paddle dimensions, they need not be exact, and no calibration is required. The cylinder, and contents, are allowed to stand at the same temperature and readings are taken at more or less frequent intervals (according to the type of oil) of the volume of oil settled out from the water. From these readings, a maximum rate of settling, called the "demulsibility," is easily taken from a table.

A German test, used for steam engine cylinder oils, would appear at first sight to discriminate against the good oils containing compounding, in the attempt to eliminate the poor oils which contain soap. Examination of the experience with the test, however, shows that the method of agitation is not very effective, so that only oils which contain soap will emulsify. Good oils, even if they are compounded, will not emulsify. The test here described might be so modified as to make it applicable to steam engine cylinder oils, but this has not yet been attempted, and in considering the results obtained with the test for demulsibility, compounded oils have been omitted, except where noted.

It has been found that the majority of oils on the market are either very good or very poor. The best transformer, dynamo and turbine oils settle out in a minute or less, thus showing a demulsibility of 1200 c.c. per hour, which is the highest value on the arbitrary scale adopted. On the other hand, when an emulsifying marine engine or crank case oil is tested, no oil will settle out of the emulsion up to the end of the hour that the test is continued, and the demulsibility is recorded as zero.

Comparison with chemical tests shows that the stirring tests are the more sensitive, and this is in agreement with the experience of others. This explains why it is has been such a troublesome

problem to chemists, why one oil would emulsify and the other would not, when according to their tests both oils were equally pure. The stirring test shows that a minute amount of impurity, which cannot be detected by chemical means, will cause a marked increase in emulsification.

Oils which have a suitable demulsibility will not emulsify in use, but there is still the trouble that, after a considerable length of time, they may disintegrate and deposit sediment, due to oxidation, polymerization or some other similar chemical change. On this account an investigation of used oils was undertaken, and it was found that there was a marked decrease in demulsibility with continued use. The conditions of operation are so different in different power plants, that exact values cannot be given for the rate of deterioration to be expected, but it is believed that the test should prove of great assistance to power house engineers in keeping track of the deterioration of the oil in their plants.

STUDIES ON PAPER PULP.*

By W. H. Smith.

[ABSTRACT.]

SEVERAL paper pulps, each representing a different method of preparation and, with one exception, of American manufacture, have been examined to determine their chemical properties in terms of the amount of ash, cellulose, and methoxyl, the yield of furfural and methylfurfural, and the copper number. Using the same pulps, the loss in weight produced by reagents causing oxidation and hydrolysis, and the increase in weight on nitration, have been determined. The effect of sunlight, temperature, and active oxygen on the chemical constants obtained with ground wood has been ascertained.

Centrifugal versus Reciprocating Boiler Feed Pumps. M. W. EHRLICH. (*Electrical World*, vol. 68, No. 20, November 11, 1916.)—Many central electric lighting, heating and power companies are favorably considering the centrifugal pump with steam-turbine drive as an auxiliary in boiler operation. In the moderate unit, either motor or turbine driven compares favorably in first cost with

* Technologic Paper No. 88.

reciprocating pumps. The centrifugal is compact and occupies a small floor space for a given capacity, and is therefore suitable where space conditions are important. In small sizes the centrifugal pump is relatively uneconomical, but in moderate sizes the economy compares favorably with that of a reciprocating steam pump.

The centrifugal unit is of simple construction without air chambers or valves, and delivers a steady flow of water so essential to the accuracy of measuring instruments used in power plant operation. The operating and maintenance costs are low, but under conditions of fluctuating load requiring a variable pump speed, the economy is poor and the reciprocating pump will be found preferable. While practice has shown that for central station power plant service the steam turbine driven pump is most reliable, and that motor driven pumps are advisable as duplicates or relays, it is still a debatable question whether centrifugal pumps for boiler feed are desirable in plants of less than 3000 boiler horsepower and 125 pounds pressure. The minimum size of installation seems to be a 250 gallon per minute unit operating against 300 feet total head requiring a 40 horsepower electric motor or steam turbine, the pump being a three-stage unit.

Magnetic Properties of Iron-Cobalt Alloys H. F. KALMUS AND K. B. BLAKE. (Canada Department of Mines, Mines Branch, Report No. 413, 1916.)—Iron-Cobalt alloys approximately to the composition Fe_2Co are produced in sound ingots only with difficulty. While fairly strong, the alloy is brittle, though annealed samples show approximately the same tensile strength as pure iron. It may be forged with considerable readiness, after which it has nearly twice the strength of pure iron. The magnetic properties of the alloy, however, should render it of great value in parts of electromagnetic apparatus where extreme magnetic densities are required. Its high magnetic saturation value is readily observed by the simplest test with a hand magnet, that is the hand magnet will lift considerably heavier pieces of the alloy than of pure iron.

The best castings have a saturation value of 10 per cent. to 13 per cent. higher than that of pure iron. Their maximum permeability is 13,000 at a density of 8000 gausses. This is considerably lower than the corresponding value for pure iron, but much greater than that for standard transformer steel and other commercial materials. The hysteresis loss of the alloy is less than for the best grades of commercial transformer steel at densities of 10,000 gausses, and about the same as for commercial transformer iron at the corresponding densities, at densities of about 15,000 gausses. The specific electric resistance is about 10 microhms. The most important property of the alloy Fe_2Co is its permeability in medium fields. Through the range of magnetizing force of 50 to 200 gilberts per square centimeter, the permeability is approximately 25 per cent. greater than that of pure iron or of commercial grades of transformer steel or iron.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE OPTICAL PROPERTIES OF LIGHT FILTERS.[1]

By C. E. K. Mees.

[ABSTRACT.]

IN discussing the optical properties of light filters for use in photo-engraving and color processes, the subject is divided by the author into two parts: (*a*) the optical properties of perfect filters; (*b*) the optical properties of imperfect filters. Under the first division, mathematical expressions are given for the two principal aberrations suffered by light in passing through a plane parallel filter, namely, curvature of field, and spherical aberration. Numerical application is made to the most unfavorable case occurring in practice. The results found prove that no detrimental or even sensible action occurs. Difference in magnification due to the use of filters of different colors is next considered. It is found that for red and blue filters the difference is of the order of one part in five thousand, or negligible. Compensation for this can be secured by making the filters of slightly different thicknesses. In testing imperfect filters, the author made use of a telescope of long focal length, and a test object formed of illuminated squares. Photographs of the appearance of the image with imperfect filters interposed are given. The effects of poor grade glass, cylindrical curvature, and cell pressure are shown. In examining high grade filters, a resolution test is used. Finally formulæ for change in magnification due to filters of different thickness, and to filters having spherical boundary surfaces forming a lens of power dP, are deduced, and verified by means of actual tests in a specially designed optical apparatus.

* Communicated by the Director.

[1] Communication No. 41 from the Research Laboratory of the Eastman Kodak Company.

Efficiency of Propulsive Machinery and Developments in Naval Engineering. H. C. DINGER. (*Proceedings of the American Society of Mechanical Engineers,* December 5–8, 1916.)—Reports made in 1912 on the relative performance of turbine-engined and reciprocating-engined naval vessels indicated the superiority of the latter for battleship propulsion. Trials of vessels constructed later, however, showed that the real cause of this superiority of performance lay in the faulty design of turbines and propellers. In tracing the advance in economy in turbine propulsion, as good examples of modern practice, the reciprocating-engined vessels, *Delaware, New York, Oklahoma,* the Parsons-turbine-engined vessels *Utah* and *Arkansas,* and the Curtis-turbine-engined vessels *North Dakota, Nevada* and *Pennsylvania* are selected.

So far as economy at different speeds is concerned, it is shown that there is but slight choice between the different types of machinery when they have the proper propeller efficiency. At very low powers the reciprocating engine is about as economical as the geared cruising turbine, and both of these are more economical than the directly connected cruising turbines; and it is evident that matters other than economical performance should decide the question of type of prime mover. When losses are guarded against it is the range of temperature that really counts in securing efficient propulsive machinery; hence the most effective measures are obviously the use of superheat and the highest practicable vacuum, the best possible utilization of feed-heating apparatus, and the economical operation of auxiliaries. The latter can become very wasteful, but in the best cases the percentage of available heat used by them has been reduced to about 5 per cent. of the total fuel power.

The geared turbine and electric drive are recent innovations which show decided economy and a material saving in weight over directly connected units. For large capital vessels the electric drive is to be preferred on account of (1) greater flexibility in shaft and piping arrangements, (2) better economy at cruising ranges, (3) better arrangement of generator rooms, boilers, etc., (4) better handling conditions and greatly improved power for backing, and (5) the practicability of using high superheat; also (6) parts of machinery can undergo repair while other parts are in operation at a very large percentage of the total power of the vessel. In general terms, the problem of the naval engineer is largely one of saving weight and space, and the principal method of accomplishing this is to install high-efficiency machinery and to enlist the co-operation of the industrial engineers of the country.

NOTES FROM RESEARCH DIVISION, ELECTRICAL ENGINEERING DEPARTMENT, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.*

A RESEARCH on "Tractive Resistances to a Motor Delivery Wagon on Different Roads and at Different Speeds," by A. E. Kennelly and O. R. Schurig, has recently been issued from the Electrical Engineering Department of the M. I. T., as its Bulletin No. 10. It is a reprint of a paper read before the American Institute of Electrical Engineers in June last. The research was carried out in and near Boston in 1915-1916, under an appropriation from Mr. Thomas A. Edison, and also from the Gould Storage Battery Co.

Measurements of tractive resistances of various kinds of vehicles have been made and recorded for many years; but the methods of analyzing and presenting the results as contained in this report, appear to be new, and have certain advantages. The authors define the tractive resistance of an electrically self-propelled vehicle, on a level road, in the absence of wind, as the horizontal force which, applied to the vehicle at the actual steady running velocity, would develop a power equal to the battery output after deducting from the latter all losses in the motors, gear, and internal car-wheel mechanism; *i.e.*, all losses from battery terminals to wheel spokes. The horizontal pull overcomes the resistance of the tires and roadbed, as well as the resistance of air displacement. It may be expressed either in kg. per metric ton of total vehicle weight, or in equivalent grade. A tractive resistance of 1 per cent. equivalent grade means, therefore, that the tractive effort which must be applied to the vehicle, on a level road, to overcome tire and road resistance, as well as air resistance, at a given speed, would suffice to drive the same vehicle at that speed up a 1 per cent. grade, in the absence of all resistances of air, tires and roadbed, as well as of all internal frictions, such as those of axle, gears, and driving motor.

The vehicle on which the tests were made was a 450 kg. (1000-lb.) electric truck, weighing from 2140 kg. to 2400 kg., with solid rubber tires and running at speeds from 13 to 25 km. per hr. (8 to 15.5 miles per hr.). The results indicate that

* Communicated by the Director.

on smooth roads, the road-and-tire resistance is constant over the above range of speeds; and varies from less than 1 per cent. equivalent grade (0.85 per cent.) on the best hard roadbed, to 1.6 per cent. on smooth soft roadbeds. On rough roads the tractive resistance increased with the speed, owing to impact. The additional resistance due to impact was greatest on the roughest roads. At 20 km. per hour, the air-displacement resistance of the truck was a little over one per mil grade (0.1 per cent.). The total range of equivalent grade of tractive resistance encountered in the tests was from 0.93 to 2.7 per cent.

Long Life Tungsten Lamp. ANON. (*Electrical World,* vol. lxviii, No. 17, October 21, 1916.)—It is well known that when a tungsten filament is operated in an evacuated bulb under ordinary conditions, the resistance of the filament gradually increases, thus lowering its temperature, and the bulb is progressively darkened by a black deposit of vaporized tungsten. Both these effects contribute to lower the efficiency and candle-power of the lamp. Heretofore, in order to increase the life of a lamp at a given efficiency, various solid halogenous compounds of low vapor tension, such as potassium iodide, have been placed in the lamp. These compounds are placed in the lamp in such a position that when the filament is at normal incandescence and the bulb is well evacuated there is evolved an atmosphere which is chemically active to the metal of the filament at substantially the pressure of a high vacuum.

Roy Winne of Schenectady, N. Y. (patent, No. 1,197,705), has discovered that the useful life of a lamp may be further increased by placing in the bulb with a regenerative compound of the above nature a very small amount of gas, preferably nitrogen. Ordinarily, the pressure of the gaseous atmosphere should be less than 100 microns, and usually within the range of about 10 to 50 microns, or 0.010 to 0.050 mm. of mercury. To illustrate the effect of the novel filling combination on the life of the lamp, a 125-volt, 100-watt lamp having a drawn tungsten filament was provided with a small amount of potassium thallium chloride placed in the same way as in a vacuum lamp. The bulb was evacuated, and then enough dry nitrogen was admitted to produce an atmosphere of about 25 microns (0.025 mm. of mercury) pressure. The lamp was then sealed off and operated at a specific consumption of 0.95 watt per candle. After 1900 hours the candle-power had fallen off only to 96 per cent. of its original value. During the operation of the lamp the resistance of the filament repeatedly increased several per cent., and then came back to normal. In the absence of the nitrogen the initial efficiency of a lamp of this type containing potassium thallium chloride would have fallen to about 80 per cent. in about 1000 to 1200 hours.

THE FRANKLIN INSTITUTE

(Proceedings of the Annual Meeting held Wednesday, January 17, 1917.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1917.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 9.

Mr. Charles E. Bonine, Chairman of the Committee on Science and the Arts, reported the conditions of the work of the committee.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-president, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Coleman Sellers, Jr., Vice-president (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

G. H. Clamer, Theobald F. Clark, Walton Forstall, Benjamin Franklin, Harry F. Keller, Richard Waln Meirs, George D. Rosengarten, William C. Wetherill, Managers (to serve three years), Nathan Hayward, Manager (to serve two years).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1916, with the Reports of the various Committees of the Institute and Board of Managers.

Mr. Charles E. Bonine, Chairman of the Committee on Science and the Arts, introduced Dr. Edwin Fitch Northrup, of Princeton, New Jersey, to whom had been awarded the Elliott Cresson Medal for his electric furnace and high temperature investigations.

The President presented the Medal and accompanying documents to Dr. Northrup, who thanked the Institute for the honour it had conferred upon him.

Harry Fielding Reid, C.E., Ph.D., Professor of Dynamical Geology and Geography, Johns Hopkins University, Baltimore, Md., presented the paper of the evening, entitled, "The Panama Slides." The speaker described the location and general character of the canal, devoting especial attention to the Gaillard Cut and the Culebra region. Consideration was given to the material of the slides and the encircling hills as well as the nature of the movement of the slides. The progress of the slides and the probable outlook for the future were also discussed.

After a discussion in which Messrs. Wetherill, Bond, Graham, Penrose, and others participated, the thanks of the meeting were extended to the speaker.

On motion of Mr. Penrose, duly seconded, the thanks of the Institute were extended to the tellers of the election for their services.

Prof. L. F. Rondinella called the attention of the members of the Institute to the fact that they were meeting on the anniversary of the birth of Dr. Franklin and referred to the wreath placed by the Poor Richard Club under the Sully portrait of Franklin to the right of the President's chair. He pointed out Franklin's claim to the appreciation of all Americans and especially of Philadelphians, and his importance in the history of our country was compared with that of Washington and Lincoln. The speaker felt that Franklin's birthday should be celebrated in a more fitting way, and that the University of Pennsylvania and the American Philosophical Society (both founded by Franklin) would be glad to coöperate in arranging such a celebration. Upon Prof. Rondinella's motion, duly seconded and carried, it was—

Resolved, That the President of the Institute be requested to appoint a Committee on Celebration of Franklin's Birthday to consist of three members of the Board of Managers. This committee to confer with similar committees that may be appointed by the University of Pennsylvania and the American Philosophical Society upon invitation of the Institute's secretary and to arrange for a joint annual celebration, and reporting its recommendations to the Board of Managers for action.

Adjourned.

R. B. OWENS,
Secretary.

REPORT OF THE PRESIDENT.

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1916.

To the Members of The Franklin Institute:

Your Board of Managers instruct me to report to you upon the work of the Institute for the year ending September 30, 1916, as follows:

Your Board, in their report for the year ending September 30, 1915, made an appeal to the membership of the Institute for the completion of the so-called Wahl Fund; a fund necessary to be raised to meet the conditions laid down in the will of our late Secretary, the distinguished Dr. William H. Wahl, as precedent to the receipt by the Institute of his estate of approximately $90,000. It is gratifying to be able to report that this fund has been completed and that the estate of Dr. Wahl has been transferred to the Institute as, and under the conditions, desired by him. It is particularly gratifying to be able to report that all the money received for the Wahl Fund came from members of The Franklin Institute.

The Wahl estate and subscriptions, with the Shippen bequest (referred to in the Annual Report of last year, but received during the year covered by this report) increase the productive funds of the Institute approximately $300,000 and practically double the Institute's endowment fund as it stood a year ago.

The regular income of the Institute, for the first time in its history, so far as known to us, is sufficient for carrying on the work immediately in hand. It offers no margin applicable to desirable extensions in the scope of

our work. Such extensions will not be undertaken until the assured income of the Institute is sufficiently increased to justify them.

The Institute's new Building Fund has been increased during the year through the sale of the Sixteenth and Arch Streets properties by $55,000. The Institute owned these properties through the generosity of one of its members. They stood on the books of the Institute as valued at $82,000. The Board of Viewers, apportioning the Parkway damages, awarded to the Institute for the properties (and for interest from the date of condemnation) $137,329.50, or approximately $55,000 more than the properties cost the Institute. The Institute's Building Fund now amounts to about $225,000. There is now in the hands of the Board of City Trusts the so-called John Scott Fund, which must ultimately come to the Institute, and which is applicable to the Building Fund, and amounts to approximately $40,000. This makes the total amount now in sight, or ultimately available to the Institute, about $265,000. This is in addition to the very valuable building site located at Nineteenth and Race Streets, on Logan Square. Your Board of Managers believe it will not be wise to proceed with the erection of a building until the present Building Fund of $265,000 has been about doubled, and the normal income of the Institute has been sufficiently increased to justify the undertaking of the coincidentally added obligations.

Your Board of Managers believe that the work the Institute is doing, and which is widely known as good and useful to the citizen, and to the City, State and Nation, will ultimately attract the funds necessary to the erection and endowment of a building better located and more nearly adequate to the accomplishment of the Institute's purposes.

The figures that I have given above are set out in detail and with more exactness in the reports of the Finance Committee, Mr. Forstall, Chairman, and of the Endowment Committee, Mr. Howson, Chairman.

At this writing the Institute owes no money other than current accounts. The "Bills Payable," now (January, 1917) among our liabilities, are debts of one department of the Institute to another.

Your Board, in this general report, cannot do more than briefly comment upon the reports of the several committees which will appear in the 1917 edition of the Year Book.

The report of the Library Committee, Mr. Morgan, Chairman, clearly indicates the importance of a new building for the Institute. It emphasizes what must be known to every member of the Institute who visits our library, the utter inadequacy of our stack and cases. We are compelled to put books wherever there is room for them in the building without reference to their protection or to the convenience of the user. There is no doubt that the library would be greatly more valuable to the citizens of Philadelphia if housed in rooms of adequate size and permitting a more intelligent arrangement.

The report of the Committee on Museums, Mr. Outerbridge, Chairman, is a record of valuable additions of interesting models, etc., contributed to the Museum during the past year.

The report of the Committee on Meetings, Mr. Rogers, Chairman, contains a list of the papers presented at the stated meetings of the Institute, with interesting comments on the May meeting, at which the Franklin Medal

was presented to Professor Theodore William Richards and to Dr. John J. Carty, and the Elliott Cresson Medal to Mr. Theodore N. Vail, President, for the American Telephone and Telegraph Company. Addresses were made by Dr. Carty and Mr. Vail. An address by Professor Richards, who was too ill at the time to attend the meeting, was read by Dr. Hoadley. Following the addresses the American Telephone and Telegraph Company gave an interesting demonstration of transcontinental and wireless telephony for the benefit of the Institute's members and guests. This was the first exhibition of the wireless telephony given in our City.

The report of the Committee on Instruction, Mr. Paul, Chairman, gives convincing evidence of the continued good work of the School. The Committee on Instruction was compelled to accept the resignation of Professor William H. Thorne, for thirty years Director of the School. Mr. Simeon van T. Jester, Assistant Director of our School, and otherwise experienced in educational work, was elected Director as successor to Professor Thorne. The membership of the School during the year was about fifteen per cent. greater than during the previous year.

The report of the Committee on Elections and Resignations of Members, Mr. Gibbs, Chairman, indicates that the Institute has not grown materially in numbers during the past year—the membership list having increased but thirty-one in the twelve months. The Institute, during the year, has not made any special effort to increase its membership.

The report of the Committee on Publications, Mr. Levy, Chairman, is of the usual encouraging character. One matter in connection with the Committee's work during the year, to which your Board of Managers wish to call attention, is the mechanical make-up and appearance of the JOURNAL. The character of the paper has been improved, the margins have been increased, the JOURNAL is now sewed instead of stapled as heretofore. These improvements add greatly to the comfort and pleasure of the user of the JOURNAL, as well as to the JOURNAL's general appearance and permanent character.

The report of the Committee on Sectional Arrangements, Mr. Day, Chairman, is practically a report of the meetings held during the last year. The attendance many times taxed the capacity of the hall. The meetings held under the auspices of this Committee last year were particularly successful and valuable.

The report of the Committee on Science and the Arts, Mr. Bonine, Chairman, evidences the continuation of the good work of the Committee, and further, that the value and importance of the Committee's work is becoming more widely recognized year by year. One evidence of this is the number of applications for investigation received: in 1914, nine; 1915, sixteen; and 1916, twenty-five.

As time passes the Institute occupies a larger space in the horizon of Philadelphia's affairs and of its general activities. This is manifested in the greater extent to which the public journals take notice of its proceedings, and in the size and character of its audiences. It is a condition largely created by the eminence of the men who come to the Institute to tell their message in the domain of science and the arts. To these eminent men the Institute offers an immediate audience often as large as its audience room will accom-

modate, and, through its JOURNAL, a multitude of readers whose habitat is conterminous with the world of scientific thought.

Members of The Franklin Institute, we, your Board of Managers, believe ourselves justified in reporting to you that the work of your Institute continues to be good. But we can only satisfy our sense of duty, and justify our succession, to those far-sighted and devoted men—the founders of the Institute—by relating this actual "good" to an ideal "better" and devoting ourselves to its accomplishment. To this ambition we each year dedicate ourselves anew; and at this, our ninety-fourth Annual Meeting, and on this, the two-hundred and eleventh birthday of our great exemplar, Benjamin Franklin, we again bespeak your encouragement and coöperation.

Respectfully submitted,

The Board of Managers,

WALTON CLARK,

President.

PHILADELPHIA, January 17, 1917.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of the Stated Meeting held Wednesday, January 3, 1917.*)

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, January 3, 1917.

MR. C. E. BONINE *in the Chair.*

The following reports were presented for first reading:

No. 2669.—The Telescribe. Advisory.

No. 2678.—McKeen Motor Car. Advisory.

The following reports were presented for final action:

No. 2677.—"Midget" Marvel Flour Mill.

Alfred Rishworth Tattersall recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

No. 2682.—Hooven Automatic Typewriter

Edward Longstreth Medal of Merit to the Hooven, Owens, Rentschler Company. Thomas A. McCall and John H. Pillings recommended to the City of Philadelphia for John Scott Legacy Medals and Premiums.

No. 2684.—The Schoop Metal Spraying Process.

Max Ulrich Schoop recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

R. B. OWENS,

Secretary.

SECTIONS.

Section of Physics and Chemistry.—A Stated meeting of the Section was held in the Hall of the Institute on Thursday, January 4, 1917, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

R. A. Millikan, Ph.D., Sc.D., Professor of Physics in the University of Chicago, delivered a lecture on "Radiations from Atoms and Electrons." The present status of experiment and theory with respect to the nature of the disturbance of the ether, which constitutes a light wave, was described. The evidence for the discontinuous emission of radiant energy by atoms and electrons, and the bearing of this evidence upon atomic structure were discussed. The lecture was illustrated with lantern slides.

The communication was discussed by Drs. Barnes, Goodspeed, Carty, Ives, and others. A vote of thanks was extended to Dr. Millikan, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A stated meeting of the Section was held in the Hall of the Institute on Thursday, January 11, 1917, at 8 o'clock P.M., with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were read and approved.

Wilder D. Bancroft, Ph.D., Professor of Physical Chemistry in Cornell University, delivered a lecture on "Colloids." The nature of colloids and their relation to both pure and applied chemistry and to the biological sciences were discussed at length. The lecture was illustrated with experiments. The paper was discussed by Drs. Hering, Creighton, Taggart, Hepburn, and others. A vote of thanks was tendered to Dr. Bancroft, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

(*Stated Meeting, Board of Managers, January 10, 1917.*)

ELECTIONS TO MEMBERSHIP.

RESIDENT.

MR. WALTER S. CROWELL, chemical engineer, 121 East Gorgas Lane, Mt. Airy, Philadelphia, Pa.

MR. JOHN D. GILL, chemical engineer, 3144 Passyunk Avenue, Philadelphia, Pa.

MR. HAROLD GOODWIN, JR., electrical engineer, 1000 Chestnut Street, Philadelphia, Pa.

MR. W. O. GRIFFITH, Stenton and Evergreen Avenues, Chestnut Hill, Philadelphia, Pa.

MR. RICHARD C. SELLERS, civil engineer, Swarthmore, Pa.

NON-RESIDENT.

DR. HAMILTON BRADSHAW, chemist, Experimental Station, Henry Clay, Delaware.

MR. VICTOR W. ZILEN, mechanical engineer, 265 Garside Street, Newark, New Jersey.

ASSOCIATE.

MR. PHILIP WERNER AMRAM, student, 3924 Spruce Street, Philadelphia, Pa.

CHANGES OF ADDRESS.

MR. HAROLD V. COES, 5127 Pulaski Ave., Germantown, Philadelphia, Pa.
MR. LEONARD KEBLER, Avon Road, Bronxville, New York.
MR. MARSHALL MILLER, P. O. Box 232, Orono, Maine.
MR. OSCAR L. SCHEHL, 1631 Girard Avenue, Philadelphia, Pa.
DR. FIN SPARRE, care of E. I. du Pont de Nemours & Company, Room 450, du Pont Building, Wilmington, Delaware.
MR. LOUIS TAWS, 6654 Lincoln Drive, Germantown, Philadelphia, Pa.
MR. CHARLES H. WERNER, 61 Broadway, New York City, N. Y.
MR. J. S. WHITNEY, 1509 Arch Street, Philadelphia, Pa.
DR. ORVILLE WRIGHT, 15 North Broadway, Dayton, Ohio.
MR. CHARLES W. YOUNG, New Stock Exchange Building, 1411 Walnut Street, Philadelphia, Pa.

NECROLOGY.

Lt.-Col. Theodore Turrettini.—On the 7th of October, 1916, there died at his home in Geneva, Switzerland, in his seventy-second year, Mr. Theodore Turrettini, soldier, statesman, engineer and man of affairs. He was an honorary member of the Franklin Institute, having been elected September 17, 1890.

He was Colonel of Artillery in the Swiss Army and had been President of the City of Geneva; but was perhaps most widely known among Engineers for his work in connection with the development of the water power of the Rhone and the control of Lake Leman. He was a member of the Administrative Council which represented all of the interests involved in the selection of the best plan and its execution. As President of the Technical Commission, he conducted the necessary studies, made recommendations to the Council and supervised construction.

He was noted in his own country for his ability and versatility; but is perhaps chiefly interesting to us for his service as a member of the International Niagara Commission.

It will be remembered that this Commission was charged with the duty of selecting the plans for the generation of power by water and its transmission to a distance not less than to Buffalo, by the most economical method, without restriction as to the transmitting medium.

At that time a good deal had been done in rope transmission, and by the use of compressed air; but very little had been accomplished in the long distance transmission of electricity for power purposes. The projectors of the Niagara enterprise, realizing the vital importance of a wise selection, placed

in the hands of the International Commission of Engineers and Scientists the duty of selecting the best plan of those submitted by twenty carefully chosen engineers, designers and manufacturers who were invited to enter the competition.

The Commissioners were authorized to spend $22,000 in prizes for such of the plans as they considered favorably. The members of the Commission were selected with great care to obtain those best qualified; and to give the body a truly international character they were chosen from various countries.

Colonel Turrettini's reputation as a hydraulic Engineer and his recent experience in connection with the Rhone works, fitted him in a peculiar degree for this new task, and he was selected to represent Switzerland which probably then stood in the lead in scientific design and application of turbine water wheels.

The other members were Prof. E. Mascart of the College of France, Dr. Coleman Sellers, former President of the Franklin Institute, Lord Kelvin (then Sir Wm. Thomson), Chairman, and Prof. Wm. Cawthorne Unwin, Dean of the Central Institute of the Guilds of the City of London, who acted as Secretary.

The Commission sat in London in 1891 and made a thorough study of the propositions submitted. The result was the adoption of that offered by Messrs. Faesch & Piccard of Switzerland and the definite decision to employ an alternating current. This latter conclusion was not reached easily, the direct current, earnestly advocated by Sir Wm. Thomson, was fairly well understood; but the alternating current was apparently regarded as still in the experimental stage. Dr. Sellers stood out for the alternating current and his view was adopted. Lord Kelvin, visting Niagara Falls after the completion of the first power house, frankly admitted that the selection of the alternating current had been a wise choice.

Those of us who had the pleasure of meeting Colonel Turrettini when he visited the United States, still retain a vivid recollection of his handsome face, his soldierly bearing and his courteous manner.

C. S., JR.

Mr. Otto Charles Wolf was born in Philadelphia on November 11, 1856, and died at Overbrook, Pa., on December 2, 1916.

He entered the University of Pennsylvania in 1872 and soon after his graduation began his professional career as architect and engineer.

Mr. Wolf was a member of a number of engineering societies; he was vice president of the Northwestern National Bank and a trustee of the German Hospital.

He became a member of The Franklin Institute on January 5, 1883, served on its Committee on Science and the Arts in 1891 and in 1897 and on its Board of Managers from 1897 to 1913.

Mr. E. P. Borden, 421 Chestnut Street, Philadelphia, Pa.
Mrs. C. C. Febiger, 3421 Powelton Avenue, Philadelphia, Pa.
Mr. Isaac L. Rice, President, Electric Boat Company, 11 Pine Street, New York City, N. Y.

LIBRARY NOTES.

PURCHASES.

AMERICAN ELECTROCHEMICAL SOCIETY.—Transactions. Vol. 29. 1916.

AMERICAN SOCIETY FOR TESTING MATERIALS.—Yearbook. 1916

BEYER, D. S.—Industrial Accident Prevention. 1916.

BOYS, C. U.—Soap-bubbles; their Colours, and the Forces which Mould Them. 1916.

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Farquhar, A. B. Company, Ltd., Catalogue of Engines and Boilers, Steam and Gas Tractors, Sawmill Machinery, and Threshers. York, Pa., 1916. (From the Company.)

Fisher, W. C., The Potentiometer. London, no date. (From Dr. R. B. Owens.)

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Nipher, F. E., Electricity and Magnetism. St. Louis, 1895. (From Dr. R. B. Owens.)

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ERRATA.

The Partition of the Load in Riveted Joints, by Cyril Batho, M.Sc., B.Eng.

November, 1916, issue of the JOURNAL, vol. 182, p. 553.

Table I, page 564, should appear on page 553; Table III, page 569, should appear on page 574 at end of first paragraph.

The last term of the first equation on age 564 should read:

$$k\left[\times_1^2 + \times_2^2 + \cdots\cdots + (F - \Sigma \times)^2\right]$$

Page 577 referred to in column 3, Table VI, page 581, should read 584.

Line 26, page 582, should read:

Square inch of nominal rivet section in A and of only 5000.

The equation on page 592 which appears as follows:

$$K = \frac{a\,F}{10^{-4}\,A}$$

should read:

$$K = \frac{a\,F}{10^{4}\,A}$$

The letter *a* in the first equation, page 594, should read q.

$$W_s = \Sigma \frac{q^2}{2G} \cdot dV,$$

Electrolytic Dissociation in Non-Aqueous Solutions, by Henry Jermain Maude Creighton.

December, 1916, issue of the JOURNAL, vol. 182, page 745. First line, page 757, should read:

The Dissociating Power and the Degree of Association of

PUBLICATIONS RECEIVED.

Bridge Engineering, by J. A. L. Waddell. First edition, 2 volumes, illustrations, plates, tables, portrait, 8vo. New York, John Wiley & Sons, 1916. Price, $10.

Cosmical Evolution, Critical and Constructive, by Evan McLennan. Second Edition. 490 pages, 12mo. Corvallis, Oregon, author, 1916. Price, $2.50.

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University of Illinois Bulletin: Subsidence Resulting from Mining, by L. E. Young and H. H. Stoek. Illinois coal mining investigations coöperative agreement. Bulletin No. 91: Engineering Experiment Station. Urbana, Ill., University, 1916.

Iowa State College of Agriculture and Mechanic Arts. Official Bulletin. Volume xv, No. 9: Sewage Disposal for Village and Rural Homes, by C. S. Nichols, Bulletin 41: Engineering Experiment Station. 31 pages, illustrations, map, 8vo.; No. 10: A Study of Oil Engines in Iowa Power Plants, by H. W. Wagner, Bulletin 42: Engineering Experiment Station. 159 pages, illustrations, 8vo.; No. 15: Practical Handling of Iowa Clays, by Homer F. Staley, Milton F. Beecher, Bulletin 43: Engineering Experiment Station. 48 pages, illustrations, 8vo. Ames, Iowa, College 1916.

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bonds issued and outstanding, and a description of the systems of road administration, fiscal management, and other factors affecting road improvement in each state. 74 pages, 8vo. Washington, Government Printing Office, 1917. Price, ten cents.

Steam Motor Vehicles. A. DOBLE. (*Society of Automobile Engineers Bulletin*, vol. xi, No. 2, November, 1916.)—Ten years ago steam cars, while not in number in use comparable with gas cars, were produced on a quantity basis. The highly developed White steamer of that day was universally admired and a keen competitor of its gas-driven rival. Despite its excellent record, cars manufactured under that name are now all equipped with gas engines. The Stanley steam car still survives, and has been manufactured without cessation since 1898.

The evolution of this car has been gradual and conservative, and it has enjoyed a well merited reputation for service at low cost. A fire-tube boiler and locomotive-type engine have been used from the first. Improvements have been added only when there was a well recognized demand. Thus have been added those necessities of modern motor cars, such as electric lights, stream-line bodies and one-man top. A condenser was adapted to the car in 1914, and as a result about 200 miles can be covered in one filling of the boiler. Kerosene is now used in the main burner (with gasoline for starting and for the pilot), and the mileage per gallon is high. The fusible plug has been abandoned in favor of a thermostat for shutting off the fuel in case the supply of water runs short.

A large number of more or less ineffectual attempts have been made to produce a satisfactory steam-car by persons ill-informed on the actual requirements and apparently lacking in the necessary understanding of automobile-production conditions. With the introduction of the long-stroke high-speed engine in Europe, the steam car rapidly fell behind in the march of progress. It should not be inferred that motor vehicle makers erred in selecting the gasoline engine. The market demanded cars in great number, and the makers chose the only practical power plant available. No one wanted a vehicle that emptied a horse trough every 20 miles. Few drivers were equal to the task of properly feeding the boiler or of devoting from a quarter of an hour to an hour and a half to starting.

With recently perfected equipment steam cars can run 1000 to 1500 miles on one filling (24 gallons) of the water tank. Boiler troubles have been minimized and it has been finally discovered that kerosene can be ignited by the electric spark with certainty and regularity, thus eliminating the former inconvenience of "firing-up." A water-tube type boiler and a single-expansion uniflow engine are noteworthy features of the new equipment.

CURRENT TOPICS.

Rubber Sponge. A. H. KING. (*Metallurgical and Chemical Engineering,* vol. xv, No. 12, December 15, 1916.)—Rubber sponges have been in use for quite a number of years, but until recently no one has attempted to utilize their rather peculiar properties in any other way than as a substitute for the natural sponge. Among the many methods of preparation, the time-honored practice has been to mix with the batch some material such as ammonium carbonate, which at the temperature of vulcanization gives off a considerable volume of gas, and thus causes porosity.

Because of its cellular structure, rubber sponge has several very peculiar properties; for example, it has the lowest apparent specific gravity of all solid bodies, its value being about 0.05. In spite of its cellular structure it is water-tight and very nearly gas-tight. While it is honeycombed with minute cells, each cell is an individual unit and the rate of diffusion of gases through it is comparatively low. Perhaps one of the most important uses to which it has been applied is in the preparation of life-preservers. It will not water-log, is light, conforms easily to the lines of the body, and is not ruined by a pin-prick. A life-raft made with rubber sponge is as nearly proof against careless handling as one can be. All sorts of floating devices, such as buoys, markers, etc., may be improved by its use. A promising application is as a tire filler for automobiles. The most satisfactory tire filler available to date is air. It is now proposed to use rubber sponge molded to fit the inside of the tire casing, and in this manner produce a puncture-proof tire. The car still rides on air, but the air is confined in innumerable little sacs.

Hard rubber sponge is also available. It is prepared from soft rubber sponge by further vulcanization, and has many applications as heat insulating material, and, where lightness is desirable, to many minor structural parts. It has in fact considerable strength, and has been proposed as a material for the framework of aeroplanes. It has also been recommended as a material for constructing automobile bodies.

New Electrical Device for Detecting Gas. C. M. MEANS. (*Coal Age,* vol. 10, No. 25, December 16, 1916.)—The portable electric miner's lamp whose use is constantly increasing, will not detect the presence of gas, and it is the present practice to use the ordinary flame safety lamp for that purpose. The device under consideration is intended to be used in testing for gas in connection with electric lamps. It consists essentially of two glowers connected in series and

placed in a vertical position side by side. These glowers are inclosed with glass and gauze, the glass being for observation purposes and the gauze to allow free circulation of air or gas and still prevent the communication of flame to the outside. The device is not at all likely to ignite gas even if the glass is broken, as the temperature of the glowers cannot be raised to the ignition point of a mixture that can be ignited. This indicates the possibility of making a perfect device that will not ignite methane under any circumstances. It can be placed close to the roof where gas is most likely to be found, requires no adjustment, and should be equally reliable under all conditions of air.

The presence of gas is determined by comparing the relative brilliancy of the two glowers. In case gas is encountered one of the glowers brightens and the other dims. Exact percentage of gas cannot be ascertained but can be approximated with a little practice. The principle employed is the use of one glower that will give catalytic action when in the presence of gas and another arranged in the same plane which will not. The glower possessing catalytic properties heated to a proper temperature by some external means will increase in temperature when brought into contact with methane. The glower which does not possess this property is raised to the same initial temperature, but dims when brought into contact with gas, due to the increased resistance of the other glower. So long as the two are in air, they remain at the same temperature and glow alike. Both glowers are made of the same material, but they have undergone a treatment that renders one highly catalytic and the other non-catalytic. By allowing the glowers to be energized for a period of time in mixtures containing high percentages of gas, they may be volatilized. By high percentages is meant 20 per cent. methane or more. However, if properly operated there is no occasion for trouble, even at these high percentages, since if the temperature is high, the limit of explosibility has passed.

Modern Transformer Development. M. M. SAMUELS. (*Electrical World,* vol. 68, No. 21, November 18, 1916.)—Probably the most remarkable progress in electrical construction is typified by the evolution from the first transformer to present-day standardized apparatus rated as high as 140,000 volts, this great stride taking place in the short period of only thirty years. Transformers are now being built for very high voltages and ratings for both single- and three-phase circuits. To give an approximate idea of the enormous size of modern transformers for average installations, it may be pointed out that the 10,000-kw., three-phase, 6,600-66,000-110,000-volt units which have been installed by the Tennessee Power Company in its various power houses on the Ocaee River, occupying floor space of approximately 20 by 8 feet, are about 19 feet high and weigh approximately 200,000 pounds. Since, as is evident, such

apparatus could not be shipped assembled, the tanks had to be riveted together in the field. This, of course, requires special care since the facilities of the modern transformer factory are not available in construction camps, the latter being generally located at a considerable distance from any industrial centre.

Indoor-type transformer tanks are built mostly of corrugated steel and are mounted on cast-iron bases. Steel bases are being used more extensively than they formerly were, however, on account of the fact that modern welding methods permit attaching them to the tanks very easily. Since indoor transformers of large rating are always water-cooled, no special radiators are required, the tank surface in addition to convection currents in the water being sufficient to carry away the heat generated. In hydro-electric power houses where great quantities of water are available at little cost, the cooling water is usually taken from the intake, circulated through the transformers under the force of gravity, and discharged into the tail race, so that no elaborate water piping is required. At sub-stations, however, where city water often has to be used or when water has to be pumped at great expense, a saving can usually be realized by installing cooling facilities and recirculating the water through the transformer. Cooling towers have been used to great advantage for this purpose, but recently cooling ponds with spray nozzles are being preferred by most engineers. In steam stations it is sometimes an advantage to pass the transformer water through the water heaters, thus utilizing part of the energy lost through radiation from the transformers. Piping complications, however, sometimes arise when this arrangement is adopted which interfere with the high-tension wiring.

Reverting to transformer construction, it may be pointed out that bushing troubles have been practically eliminated and tank construction so improved that leakage now occurs very rarely. High voltage testing transformers are available at the present time in all test rooms, the highest test pressure used for practical purposes being about 750,000 volts. By installing the transformer and high tension switching in inclosures and interlocking the compartment door with the low-tension oil switch of the transformer, the operation of these high-tension test sets has been made practically hazardless.

Homogeneity of Expansion of Invar. C. E. GUILLAUME. (*Comptes Rendus*, vol. 165, No. 26, p. 966. December 26, 1916.)—The minimum value of the temperature coefficient of the ferro-nickels is very marked with respect to the ratio of their components, and variations from this ratio in invar, properly so-called, is accompanied by a decided increase in the value of the coefficient. The addition of other metals or metalloids, of which several (Mn, C, Si) are necessary to insure workable alloys, raise the minimum value itself, and as the exact composition of a commercial cast can never be exactly

controlled, the expansion coefficient varies in an appreciable degree from one cast to another. It is therefore essential, in applications to precision apparatus, to make separate determinations upon samples drawn from each cast.

It may properly be asked if such a determination upon a given sample is fairly representative of the entire cast, since the rate of expansion is governed not alone by the composition but as well, in a great measure, by the treatment to which the piece has been subjected. This is a most important question in many applications, particularly in geodetic base-line bars and wire measures, and in pendulums. The examination of bars 4 meters in length is tedious and costly and the determination is made upon a bar 1 meter in length from the same ingot and subjected to the same treatment. Pendulums are standardized from a representative sample of a given heat. Wires are drawn from selected material and calibrated by the examination of several samples. An additional complication occurs in wires. In fact, when pieces of considerable volume are used, local variations of the coefficient of expansion average together into a uniform mean value, while in pieces of small dimensions, marked irregularities occur. For instance, in watch hair-springs, whose thickness is of the order of one one-hundredth of a millimeter, the effects of segregation are very marked. Despite the multiplicity of factors which affect the expansion of invar, the properties of a sample are a satisfactory criterion, even for precise measuring apparatus, of the part represented.

Origin of the Canning Industry. A. W. BITTING AND K. G. BITTING. (*Canning and How to Use Canned Foods,* National Canners' Association, 1916.)—Canning is the art of preserving a food through sterilization by heat, and maintaining it in that condition in a hermetically sealed container. In its highest development it is an attempt to maintain the food in as nearly the natural condition as possible, or in the condition in which it is usually consumed. Previous to the introduction of this method resort had to be made to pickling either in salt or vinegar, to drying to smoking, and to preserving in sugar. Each of these methods was applicable to certain products, but was productive of change in character, and was attended by so much spoilage in holding that other methods that would overcome these objections would naturally meet with success. Canning leaves much to be desired, but is a vast improvement over other methods, besides it is applicable to so many products which cannot be conserved in any other manner, and withal is so simple that it can be used in the home as well as in the factory.

The art of canning had its origin near the end of the eighteenth century when, among the military measures enacted by the French Government, a bounty of 12,000 francs was offered for an improved method of preserving foods. Nicholas Appert, an expert confectioner, brewer, distiller and chef, was among those who began experi-

menting; he worked from 1795 until 1804 before he attained his first success which consisted in heating the product and then hermetically sealing the container. He continued his efforts, using many different substances, and so perfected the process that in 1810 he published the results. He was awarded the prize and almost universally honored as the discoverer of the art of canning. Appert did his work so thoroughly and the method was so simple that others began using it as early as 1815, and it was put into commercial practice in 1820. According to his account, he packed his products in glass bottles, added sufficient water to cover, inserted the corks, and then placed them in the water bath. They were heated very gradually for varying lengths of time, depending upon the character of the food. He obtained a temperature of 190° to 200° F. in the center of the bottles, the maximum being 212° F. He used glass exclusively, and achieved results which are difficult to surpass with all our modern equipment.

Appert did not know why foods kept when treated according to his method, and ascribed it to the exclusion of outside air after applying sufficient heat to the food. Science had not progressed sufficiently to determine the real cause for keeping, and, naturally, conclusions were drawn which seemed to coincide with what appeared to be the controlling factors in practice. The French government appointed Gay Lussac to investigate the cause for keeping. He reported that spoiling is a series of oxidation changes, and that by the exclusion of the outside air these changes were prevented in bottled or canned foods. It is now known that all foods, water, air and the containers are bearers of bacteria and other micro-organisms, that the effect of heat is to destroy them, and that the hermetic container merely excludes those from without. The honor of discovering most of the fundamental principles involved also belongs to Pasteur, though his work was in reality directed along a different line.

The first application of bacteriology to canning in this country was made by H. L. Russell, of the University of Wisconsin, in 1895. He was followed by Prescott and Underwood, at the Massachusetts Institute of Technology, in 1896. Since that time sufficient work has been done to enable the processing of all lines of food products with comparative safety.

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